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Report 219

Geology of the Timmins Area

District of Cochrane

By

D.R. Pyke

1982

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FOREWORD

TIMMINS AREA

The Timmins area contains numerous occurrences of gold, silver, copper, nickel, scheelite, talc and magnesite. At the time of writing this report 32 mines, four of which are still operating, have produced approximately 2 billion dollars worth of gold. The present survey and report is an attempt to collate previous detailed mapping into a broad stratigraphic framework for the entire area.

It is hoped that the stratigraphic and structural interpretation presented here will stimulate mineral exploration in localities that have not previously been explored and hopefully aid in the discovery of new mineral deposits to allow the Timmins area to maintain its proud tradition as a major producer of Ontario's mineral wealth.

E.G. Pye

Director

Ontario Geological Survey

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IV–Fe - Tholeiites.

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GEOLOGICAL MAP

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Map 2455 (coloured)–Timmins Area.
District of Cochrane.
Scale 1:50 000.

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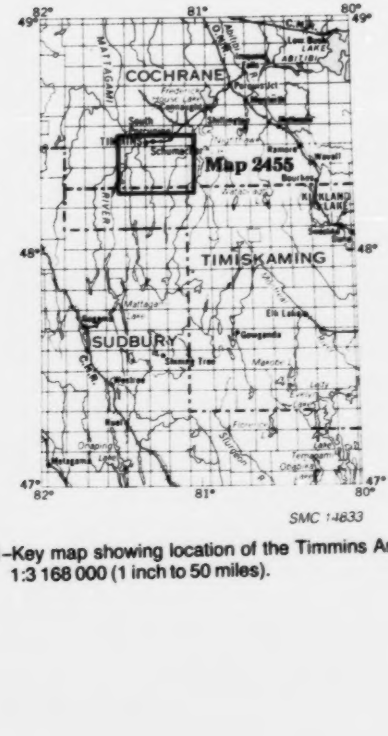
82°
81°
80°
49°
49°
C.N.R.
O.N.R.
Abitibi
LAKE
ABITIBI
MATTAGAMI
COCHRANE
Frederick House Lake
Porquis Jct.
South
Schumacher
Map 2455
Ramore
Bourkes
KIRKLAND LAKE
RIVER
48°
48°
TIMISKAMING
Mattagami Lake
Elk Lake
Gowganda
SUDBURY
Shining Tree
C.N.R.
Makobe L.
Lady Evelyn Lake
Florence L.
Sturgeon
Onaping Lake
Metagama
Temagami
Lake
47°
47°
82°
81°
80°

SMC 14833

Figure 1–Key map showing location of the Timmins Area. Scale 1:3 168 000 (1 inch to 50 miles).

ABSTRACT

This report describes the geology and the stratigraphic relationship of the mineral occurrences in the Timmins Area. The area encompasses approximately 1036 km^2 and is bounded by Longitudes 81°00′ to 81°30′ West and Latitudes 48°15′ to 48°30′ North.

With the exception of a few diabase dikes and minor Middle Precambrian sedimentary rocks, all the bedrock in the area is of Early Precambrian (Archean) age. The metavolcanics are divided into two groups, the Deloro Group and the overlying Tisdale Group; each group is divided into three formations. The Deloro Group is largely a calc-alkaline sequence, approximately 4500 m thick, and is composed mainly of flows of andesite and basalt in the lower part and dacitic flows and dacitic and rhyolitic pyroclastic rocks toward the top. Iron formation is common at or near the top of the group. Most of the Deloro Group is confined to a large domal structure in the east central part of the area. Minor ultramafic flows occur near the base of the Deloro Group, and are only exposed in the southwest corner of the area. A major change in volcanism marks the beginning of the Tisdale Group. The basal formation consists largely of ultramafic volcanic rocks and basaltic komatiites. This in turn is overlain by a thick sequence of tholeiitic basalts. The uppermost formation is largely volcaniclastic and has a calc-alkaline dacite composition. The total thickness of the Tisdale Group is about 4000 m.

Metasediments, consisting dominantly of interlayered wacke, siltstone, and lesser amounts of conglomerate form part of what is mainly a turbidite sequence. The lower part of this sequence is time equivalent to the upper part of the Deloro Group and the entirety of the Tisdale Group. This turbidite sequence, together with a thin sequence of overlying fluviatile sedimentary rocks is termed the Porcupine Group. The total exposed thickness of the group is approximately 3000 m.

Large, generally sill-like bodies of medium- to coarse-grained dunite and lherzolite were emplaced almost entirely within the Deloro Group of metavolcanics. Some of the sills are interpreted to have provided a magma source for some of the overlying ultramafic metavolcanics of the Tisdale Group.

Minor, small epizonal quartz feldspar porphyry intrusions, probably of subvolcanic derivation, were intruded into the metavolcanics. Most of these intrusions occur within a restrictive stratigraphic interval; this suggests that they may in part represent extrusive rhyolitic domes.

A small stock of biotite-hornblende trondhjemite outcrops in east central Eldorado Township, a large stock of porphyritic granodiorite underlies much of Adams and Price Townships, and a small stock of monzonite outcrops into the southeast corner of the area. The eastern margin of a large complex batholith extends into the southwest part of the area.

Northeast-trending diabase dikes of Middle and Late Precambrian Age traverse the area. Many of the north-trending diabase dikes are probably of Early Precambrian Age. Minor Middle Precambrian sedimentary rocks of the Gowganda Formation, Cobalt Group, Huronian Supergroup, unconformably overlie the Early Precambrian rocks in the southeastern part of the area.

A major structural break, the Destor-Porcupine Fault, trends northeast across the northern part of the area. North of the fault, two periods of folding can be discerned; an original north-trending series of folds were subsequently refolded about an east-northeast axis. South of the Destor-Porcupine Fault, the Shaw Dome forms the main structural feature; the axis trends about east-west across the southern part of Shaw Township.

The Early Precambrian volcanic and sedimentary rocks have undergone regional metamorphism to the lower and middle greenschist facies.

In total, 32 mines, 4 of which are still operating, have produced approximately 2 billion dollars worth of gold. Virtually all the production from the area has been from quartz carbonate veins in the metavolcanics and metasediments north of the Destor-Porcupine Fault. Although many sources have been postulated for the gold mineralization, it is the writer's contention that the ultramafic volcanic rocks in the Timmins area may have provided the main "source bed" for the gold mineralization. The gold was subsequently mobilized in large part during carbonitization of the ultramafic rocks, and deposited in structurally favourable sites. In addition to gold, abundant silver and minor scheelite have been won from the vein deposits.

A quartz-feldspar porphyry intrusion in Tisdale Township hosts a small porphyry copper deposit (8 million tons, grading 0.7 percent) which has been in production since 1960.

During 1973 to 1977, 1.1 million tons of nickel ore were milled from an orebody along the east central margin of the area in Langmuir Township. The mineralization is confined to ultramafic rocks at or near the base of the Tisdale Group.

Locally, the ultramafic rocks have been extensively replaced by magnesite; two large deposits are known, neither of which have been exploited.

Minor asbestos has been produced from the ultramafic sills in Deloro Township.

A tentative interpretation of the regional stratigraphy and structure for the general Timmins - Matachewan and Timmins-Kirkland Lake areas is given at the end of the report.

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If the reader wishes to convert imperial units to SI (metric) units or SI units to imperial units the following multipliers should be used:

CONVERSION FROM SI TO IMPERIAL			CONVERSION FROM IMPERIAL TO SI		
SI Unit	*Multiplied by*	*Gives*	*Imperial Unit*	*Multiplied by*	*Gives*
			LENGTH		
1 mm	0.039 37	inches	1 inch	**25.4**	mm
1 cm	0.393 70	inches	1 inch	**2.54**	cm
1 m	3.280 84	feet	1 foot	**0.304 8**	m
1 m	0.049 709 7	chains	1 chain	20.116 8	m
1 km	0.621 371	miles (statute)	1 mile (statute)	**1.609 344**	km
			AREA		
1 cm^2	0.155 0	square inches	1 square inch	**6.451 6**	cm^2
1 m^2	10.763 9	square feet	1 square foot	**0.092 903 04**	m^2
1 km^2	0.386 10	square miles	1 square mile	2.589 988	km^2
1 ha	2.471 054	acres	1 acre	0.404 685 6	ha
			VOLUME		
1 cm^3	0.061 02	cubic inches	1 cubic inch	**16.387 064**	cm^3
1 m^3	35.314 7	cubic feet	1 cubic foot	0.028 316 85	m^3
1 m^3	1.308 0	cubic yards	1 cubic yard	0.764 555	m^3
			CAPACITY		
1 L	1.759 755	pints	1 pint	0.568 261	L
1 L	0.879 877	quarts	1 quart	1.136 522	L
1 L	0.219 969	gallons	1 gallon	**4.546 090**	L
			MASS		
1 g	0.035 273 96	ounces (avdp)	1 ounce (avdp)	28.349 523	g
1 g	0.032 150 75	ounces (troy)	1 ounce (troy)	**31.103 476 8**	g
1 kg	2.204 62	pounds (avdp)	1 pound (avdp)	**0.453 592 37**	kg
1 kg	0.001 102 3	tons (short)	1 ton (short)	**907.184 74**	kg
1 t	1.102 311	tons (short)	1 ton (short)	**0.907 184 74**	t
1 kg	0.000 984 21	tons (long)	1 ton (long)	**1016.046 908 8**	kg
1 t	0.984 206 5	tons (long)	1 ton (long)	**1.016 046 908 8**	t
			CONCENTRATION		
1 g/t	0.029 166 6	ounce (troy)/ ton (short)	1 ounce (troy)/ ton (short)	34.285 714 2	g/t
1 g/t	0.583 333 33	pennyweights/ ton (short)	1 pennyweight/ ton (short)	1.714 285 7	g/t

OTHER USEFUL CONVERSION FACTORS

1 ounce (troy)/ton (short)	20.0	pennyweights/ton (short)
1 pennyweight/ton (short)	0.05	ounce (troy)/ton (short)

NOTE–Conversion factors which are in bold type are exact. The conversion factors have been taken from or have been derived from factors given in the Metric Practice Guide for the Canadian Mining and Metallurgical Industries published by The Mining Association of Canada in co-operation with the Coal Association of Canada.

Geology
# of the
Timmins Area
District of Cochrane

By

D.R. Pyke[1]

INTRODUCTION

Since the discovery of gold in the Timmins area in 1909, many investigators have contributed to the geological knowledge of the area. The purpose of this work was to attempt to collate previous mapping into a broad stratigraphic framework for the entire area. In the vicinity of the mines, detailed stratigraphy was well established (Ferguson *et al.* 1968); elsewhere only piecemeal sections of the stratigraphy were known, or at best implied. Because of this, much of the field mapping for this project concentrated on the least mapped areas. Time by no means permitted as rigorous or as detailed a field study as is required for the Timmins area, largely because of the size of the area coupled with the complexity of the geology. No doubt further investigation will modify the stratigraphy and structure presented here; however, it is hoped that the data and interpretation within this report will form not only an adequate base for further study, but also stimulate geological investigations within the area.

During the course of mapping numerous specimens were collected for chemical analyses as an aid in determining the stratigraphy. The location of these samples and corresponding analyses are incorporated in the report.

The boundary of the map-area for the stratigraphic interpretation has been extended north approximately 4.8 km from the original boundary of Latitude 48°30'N in order to include all the northern townships.

In addition, a tentative, yet more regional geological interpretation of the stratigraphy is presented at the end of the report in an attempt to integrate much of the regional mapping in the Timmins-Matachewan area.

---

[1] Geologist, Precambrian Section, Ontario Geological Survey, Toronto.

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OGS 10 372

Photo 1–Aerial view of City of Timmins looking east. Highway 101 crosses Matagami River in foreground.

Location and Accessibility

The Timmins area (Figure 1) covers about 1036 km^2, and is located largely within the newly established boundaries of the city of Timmins (Photo 1) which itself embraces an area 72 km by 48 km. The map-area is bounded by Longitudes 81°00′ to 81°30′ west and Latitudes 48°15′ to 48°30′ North.

Access to most of the area, particularly the northern half, is good. Highway 101 traverses the northwestern part of the area. Numerous roads, seasonal and all weather, extend south into many of the townships. Parts of the area, notably east Whitney Township and adjacent Cody Township, as well as southern Eldorado and north Douglas Townships, are best reached by helicopter (Photo 2).

Physiography

The region is one of low relief, and a thick mantle of proglacial lacustrine clay and silt covers much of the southeastern and extreme northeastern part of the area. Most of the outcrop is centred in an area incorporating south Tisdale, southwest Whitney, and northern Deloro and Shaw Townships. Local relief rarely exceeds 15 to 23 m, and extensive areas of wet muskeg (Photo 3) are com-

OGS 10 373

Photo 2–Helicopter on Redstone River in Central Eldorado Township.

mon in much of the southern part of the area. The highest relief is near the southeast corner of the area where a ridge of Middle Precambrian rocks rises 90 m above the surrounding terrain.

The western part of the area is drained northward by the Grassy, Mountjoy, and Splitrock Rivers which merge with the Mattagami River near the city of Timmins. The eastern part of the area is drained northward largely by the Redstone River and Night Hawk Lake

Previous Geological Work

Although gold was noted in the Porcupine area by E.M. Burwash (1896) and later by W.R. Parks (1899), both of whom were geologists attached to Niven's survey party; it was not until 1909 that economic discoveries were made by such prospectors as George Bannerman, Alec Gillies, Benjamin Hollinger, Sandy McIntyre, and Tom Middleton. Since then, a wide variety of geological investigations has taken place in the Timmins area, many of which have been summarized by H.D. Carlson (1967), S.A. Ferguson *et al.* (1968), and E.J. Leahy (1971).

OGS 10 374

Photo 3–Tractor road in wet muskeg in central Langmuir Township.

In 1910, A.G. Burrows of the Ontario Bureau of Mines began his epic field investigations and subsequently published a series of geological maps and reports (Burrows 1911, 1912, 1915, 1924) which have formed the base for all further geological surveys in the area. Anyone familiar with the Timmins area cannot help but be impressed with the excellence of Burrow's work. The first two maps, published in 1911 and 1912 were of a reconnaissance nature and covered all or parts of 17 townships in the immediate Timmins area at a scale of 1 inch to 1 mile. The maps of 1915 and 1924 were at a scale of 1 inch to 2000 feet, and were the results of detailed studies largely in Tisdale, Whitney, Deloro, and Shaw Townships.

In 1935, 1936, and 1937, M.E. Hurst (1939) revised and remapped part of the area included in A.G. Burrow's (1915 and 1924) maps, and also included parts of Carman, Cody, Ogden, Mountjoy, Murphy, Hoyle, and Matheson Townships in his map. This map is at a scale of 1 inch to 2000 feet and still forms a valuable geological base for much of the Timmins area.

In 1924, F.L. Finely (1925) mapped the Kamiskotia area, at a scale of 1 inch to 1 mile, which included the townships of Robb, Jamieson, Turnbull, and Godfrey.

In 1925, J.E. Hawley (1926) mapped the townships of Ogden, Bristol, and Carscallen at a scale of 1 inch to 1 mile.

In 1937, W.D. Harding and L.G. Berry (1938) mapped the townships of Carman, Thomas, Sheraton, Langmuir, and Blackstock at a scale of 1 inch to 1 mile.

In 1948, W.R. Dunbar included a map of part of the Timmins area in a paper discussing the "Structural Relations of the Porcupine Ore Deposits".

In 1950, N. Hogg (1950) included a map of part of the Timmins area in a report on "The Porcupine Gold Area".

In 1952, N. Hogg (1954) completed detailed mapping of Godfrey Township at a scale of (1 inch to 1000 feet).

In 1953 and 1954, S.A. Ferguson (1957) mapped Bristol Township at a scale of 1 inch to 1000 feet.

In 1957, a preliminary compilation map of Price Township was published (Ferguson 1957).

Ferguson (1959) compiled detailed maps (1 inch to 500 feet) of Tisdale Township, the north part of Deloro Township, and the north part of Whitney Township. Subsequently the data for Tisdale Township was incorporated into a report by Ferguson *et al.* (1968) with an accompanying map at a scale of 1 inch to 1000 feet.

In 1964 and 1965, H.D. Carlson (1967) mapped the townships of Ogden, Deloro, and Shaw at a scale of 1 inch to ¼ mile.

In 1964 and 1965, E.J. Leahy (1971) mapped the Night Hawk Lake area which included the townships of Cody, Macklem, Carman, and Thomas at a scale of 1 inch to ¼ mile.

In the years 1967 to 1971 inclusive, D.R. Pyke mapped the following townships at a scale of 1 inch to ¼ mile: Langmuir and Blackstock (Pyke 1970); Fallon and Fasken (Pyke 1973); Adams and Eldorado (Pyke 1975b); and the Redstone River area (Pyke 1978b) which included McArthur and Douglas Townships at the southern margin of the Timmins area. In 1972, Pyke (1978a) completed a combined compilation-mapping project of the Peterlong Lake area, which adjoins the south boundary of the Timmins area, at a scale of 1:50 000.

Field Work

Most of the field work for this compilation was done during the summer of 1973. An additional eight days was spent in the area in 1974, 16 days in 1975, and three days in 1976. In 1973, most of the field work was concentrated in Deloro, Shaw, Ogden, and Whitney Townships. In 1974 and 1975, most of the field work was concerned with the area north of the Destor Porcupine Fault, that is northwest Deloro Township, Tisdale Township, and north Whitney Township. As virtually all the Timmins area had previously been mapped at various scales, (*see* section "Previous Work"), the aim of this compilation was to try to integrate what was already known of the geology and supplement this where possible with additional work to determine the regional stratigraphy.

Vertical aerial photographs at a scale of 1 inch to ¼ mile (1:15 840), supplied by the Ontario Division of Forests,provided mapping control. The base map, at a scale of 1:50 000 was prepared by the Cartography Section, Ontario Division of Lands, from map-sheets of the Forest Resources Inventory of the Ontario Division of Forests.

OGS 10 375

Photo 4–Field assistants in 1973; J. Lorsong, T.L. Muir, B. Seabrook, R. Hillier, and Bolero.

Acknowledgments

In 1973, the writer was assisted (Photo 4) in the field by T.L. Muir (senior assistant) and R. Hillier, J.A. Lorsong, and B. Seabrook junior assistants. Muir, in addition to carrying out normal senior assistant duties, did extensive sampling of many of the ultramafic rocks for his post graduate work at Queen's University (Muir 1975).

Numerous discussions with J.A. Lorsong during 1974-75 and his work on the sedimentary rocks (Lorsong 1975) is most appreciated.

In 1975, the writer was assisted by Vince Vertolli (senior assistant).

Thanks are also extended to Bill Blahey and his staff, who for numerous years provided excellent service to the writer's field parties in the general Timmins area.

GENERAL GEOLOGY

With the exception of a few diabase dikes and minor Middle Precambrian sedimentary rocks, all the bedrock in the area is of Early Precambrian (Archean) age (Figure 2). Early Precambrian metavolcanics in the area are divided

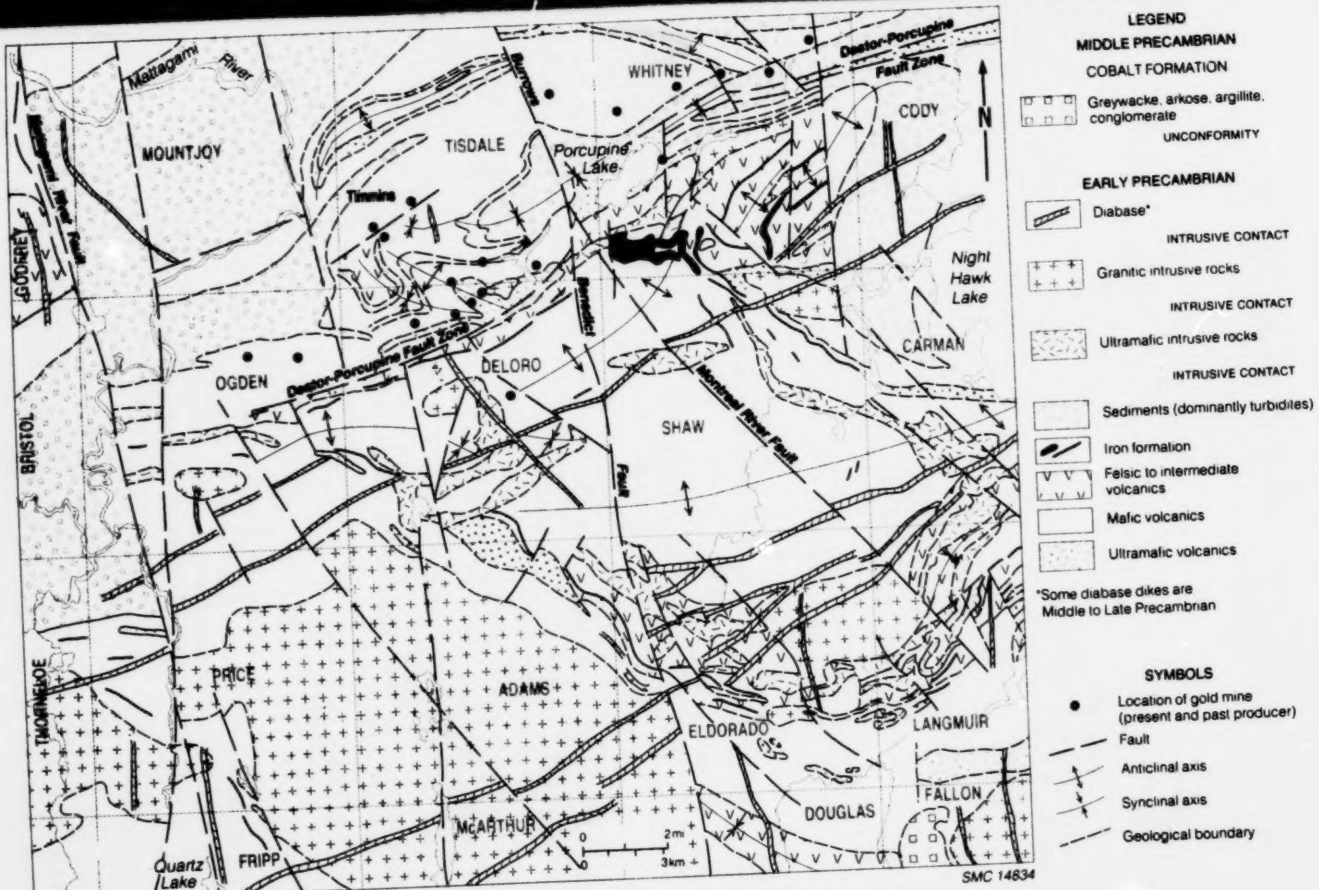
Mattagami River
Mattagami River Fault
GODFREY
BRISTOL
THORNELOE
MOUNTJOY
TISDALE
Timmins
Burrows
Porcupine Lake
WHITNEY
Destor-Porcupine Fault Zone
CODY
N
Night Hawk Lake
CARMAN
Benedict
Fault
DELORO
OGDEN
Destor-Porcupine Fault Zone
SHAW
Montreal River Fault
PRICE
ADAMS
ELDORADO
LANGMUIR
FALLON
DOUGLAS
McARTHUR
FRIPP
Quartz Lake
0
2mi
3km
SMC 14834
LEGEND
MIDDLE PRECAMBRIAN
COBALT FORMATION
Greywacke, arkose, argillite, conglomerate
UNCONFORMITY
EARLY PRECAMBRIAN
Diabase*
INTRUSIVE CONTACT
Granitic intrusive rocks
INTRUSIVE CONTACT
Ultramafic intrusive rocks
INTRUSIVE CONTACT
Sediments (dominantly turbidites)
Iron formation
Felsic to intermediate volcanics
Mafic volcanics
Ultramafic volcanics
*Some diabase dikes are Middle to Late Precambrian
SYMBOLS
Location of gold mine (present and past producer)
Fault
Anticlinal axis
Synclinal axis
Geological boundary

Figure 2–Geological sketch map of the Timmins Area.

TABLE 1 TABLE OF LITHOLOGIC UNITS FOR THE TIMMINS AREA.

PHANEROZOIC
CENOZOIC
QUATERNARY
RECENT
Swamp and stream deposits.
PLEISTOCENE
Clay, sand, gravel, till.

Unconformity

PRECAMBRIAN
LATE PRECAMBRIAN
MAFIC INTRUSIVE ROCKS
Olivine diabase

Intrusive Contact

MIDDLE PRECAMBRIAN
MAFIC INTRUSIVE ROCKS
Quartz diabase.

Intrusive Contact

HURONIAN SUPERGROUP
GOWGANDA FORMATION
COBALT GROUP
Arkose, wacke, argillite, conglomerate.

Unconformity

EARLY PRECAMBRIAN (ARCHEAN)
MAFIC INTRUSIVE ROCKS
Diabase.

Intrusive Contact

FELSIC INTRUSIVE ROCKS
Quartz and feldspar porphyry, felsite, hornblende-biotite trondhjemite, porphyritic-monzonite, porphyritic granodiorite, leucocratic equigranular granodiorite, hornblende diorite, quartz diorite, diorite.

Intrusive Contact

METAMORPHOSED MAFIC INTRUSIVE ROCKS
Gabbro, quartz gabbro, pegmatoidal gabbro.

Intrusive and Gradational Contact

METAMORPHOSED ULTRAMAFIC INTRUSIVE ROCKS
Serpentinized diorite, peridotite, and lherzolite; pyroxene hornblendite; carbonatized dunite-peridotite, talc magnesite alteration.

Intrusive Contact

METAVOLCANICS AND METASEDIMENTS
METASEDIMENTS
Conglomerate, lithic wacke, siltstone, lithic arenite, iron formation (siliceous sulphide and oxide-bearing phases, minor carbonate phases).

METAVOLCANICS

FELSIC CALC-ALKALIC METAVOLCANICS

Massive, fine-grained flows, tuff, lapilli-tuff and breccia, schistose-sericitic varieties common.

MAFIC CALC-ALKALIC METAVOLCANICS

Massive fine-grained flows, pillowed flows, amygdaloidal flows, pillow breccia, tuff, lapilli-tuff and breccia, sheared and carbonatized pyroclastics and flows.

THOLEIITIC METAVOLCANICS

Massive fine- to medium-grained flows, pillowed flows and flow breccia, amygdaloidal variolitic and epidote veined flows, minor tuff, lapilli-tuff and breccia.

KOMATIITIC METAVOLCANICS

Massive polysutured serpentinized peridotitic komatiite, olivine spinifex, massive and pillowed basaltic komatiite, pyroxene spinifex, extensive carbonate and talc alteration.

In this report, calc-alkaline is synonymous with calc-alkalic.

into two groups, the Deloro and Tisdale Groups. This terminology follows that adopted by W.R. Dunbar (1948) and subsequently used by other workers (Carlson 1967; Hogg 1950; and Leahy 1971). It might be noted, however, that these two groups should perhaps be termed supergroups when applied within the context of the stratigraphic framework of the entire Timmins-Kirkland Lake area (Pyke and Jensen 1976). Nevertheless, the group status is currently retained for this report. Of the two groups originally proposed, the Deloro Group was interpreted to be the older (Dunbar 1948). This was never firmly established because the two groups were everywhere thought to be separated structurally by the Destor-Porcupine Fault.

Of major significance for the present correlation of the volcanic stratigraphy in the Timmins area is the recognition of ultramafic flows north and south of the Destor-Porcupine Fault. If the ultramafic flows on opposite sides of the fault are correlated, then the original interpretation that the Deloro Group is older than the Tisdale Group is confirmed. Although difficult to prove, this correlation seems reasonable because both north and south of the Destor-Porcupine Fault, the ultramafic flows occur within a similar stratigraphic setting; the ultramafic metavolcanics are intercalated with basaltic komatiites, and in turn are overlain by a dominantly iron-rich tholeiitic sequence. Furthermore, the local juxtaposition of ultramafic metavolcanics on either side of the Destor-Porcupine Fault would suggest faulting along a common stratigraphic horizon.

The volcanic stratigraphy is divided into six formations, herein numbered I to VI; numbers I through III are within the Deloro Group, and numbers IV through VI (*see* Figure 19) are within the Tisdale Group. Formational names were informally introduced in a previous paper (Pyke 1975), but it is currently deemed better to retain a numbering system. The Deloro Group is largely a calc-alkaline sequence, approximately 4500 to 5000 m thick, and is composed mainly of flows of andesite and basalt in the lower part, and dacitic flows and dacitic and rhyolitic pyroclastic rocks toward the top. Iron formation is common at or near the top of the group. Most of the Deloro Group is confined to a large domal structure in the east central part of the area. A major change in volcanism marks the beginning of the Tisdale Group. The basal formation consists largely of ultramafic volcanic rocks and basaltic komatiites. This in turn is overlain by a thick sequence of tholeiitic basalts. The uppermost formation is largely volcaniclastic and has a calc-alkaline dacite composition. The total thickness of the Tisdale Group is about 4000 m.

Metasediments, consisting dominantly of interlayered wacke, siltstone, and lesser conglomerate form part of what is mainly a turbidite sequence, the lower part of which is time equivalent to the upper part of the Deloro Group and the entirety of the Tisdale Group (*see* Figure 23b) . This turbidite sequence, together with a thin sequence of overlying fluviatile sedimentary rocks has recently been classified as the Porcupine Group (Lorsong 1975). The total exposed thickness of the group is approximately 3000 m.

Large, generally sill-like bodies of medium- to coarse-grained dunite and lherzolite were emplaced almost entirely within the Deloro Group of metavolcanics. Conceivably, some of the sills may have acted as magma reservoirs, providing a source for some of the overlying ultramafic metavolcanics of the Tisdale Group. Differentiation has produced a narrow zone of pyroxenite and gabbro along the roofs of some of the sills.

Minor, small epizonal (Graton *et al.* 1933) quartz-feldspar porphyry intrusions, probably of subvolcanic derivation, were intruded into the metavolcanics. Most of these intrusions occur within a restrictive stratigraphic interval, suggesting that they may in part represent extrusive rhyolitic domes.

A small stock of biotite-hornblende trondhjemite outcrops in east-central Eldorado Township, a large stock of porphyritic granodiorite underlies much of Adams and Price Townships, and a small stock of monzonite outcrops into the southeast corner of the area. The eastern margin of a large complex batholith (Pyke *et al.* 1973) extends into the southwest part of the area.

Northeast-trending dikes of Middle and Late Precambrian age (Pyke *et al.* 1973) traverse the area. Many of the north-trending diabase dikes are probably of Early Precambrian age, although it is recognized that some are Middle to Late Precambrian in age (Leech 1965).

Minor Middle Precambrian sedimentary rocks of the Gowganda Formation, Cobalt Group, Huronian Supergroup, unconformably overlie the Early Precambrian rocks in the southeastern part of the area.

A major structural break, the Destor-Porcupine Fault, trends northeast across the northern part of the area (Burrows 1924; Hurst 1939; Ferguson *et al.* 1968).

North of the fault, two periods of folding can be discerned; an original north-trending series of folds were subsequently refolded about an east-northeast axis. Interpretation of the overall fold pattern, however, is particularly hampered where extensive faulting has occurred, as in north Whitney Township. Nevertheless, the main axis of the second period of deformation is delineated by the Porcupine Syncline in Tisdale Township (Ferguson *et al.* 1968) which in the northeastern part of the area is coincident with the Destor-Porcupine Fault. It is suggested that the second period of folding was largely accomplished by shear folding, perhaps related to the development of the Destor-Porcupine Fault.

South of the Destor-Porcupine Fault, the Shaw Dome forms the main structural feature; the axis trends about east-west across the southern part of Shaw Township. It is not known if this domal structure is the result of the same superimposed folding which affected the rocks north of the Destor-Porcupine Fault. Conceivably, the doming may have resulted from the diapiric action of an underlying granitic body; this can be inferred from a negative Bouguer anomaly coincident with the dome (Middleton 1976).

The Early Precambrian volcanic and sedimentary rocks have undergone regional metamorphism to the lower and middle greenschist facies.

Ferguson *et al.* (1968) have given a comprehensive description of the gold-bearing veins and mines of Tisdale Township, and H.D. Carlson (1967) has described the mines and showings in Ogden, Deloro, and Shaw Townships. Virtually all the production from the area has been from quartz-carbonate veins in the metavolcanics and metasediments north of the Destor-Porcupine Fault. In total, 32 mines, four of which are still operating, have produced approximately 2 billion dollars worth of gold. Most of the auriferous quartz veins tend to be along anticlinal axes and many are in close proximity to stocks of quartz-feldspar porphyry (Ferguson *et al.* 1968). A number of sources have been postulated for the mineralization; most theories (Carter 1948; Ferguson *et al.* 1968; Griffis 1962) have implied derivation of the gold from small stocks of quartz-feldspar porphyry, generally considered to be of subvolcanic origin (Griffis 1962; Graton *et al.* 1933). Other less popular theories have postulated lateral secretion of the vein material from the nearby volcanic rocks (Hurst 1935) or derivation from the large granitic batholiths (George 1967; Jones 1948), generally considered to be of Algoman age. More recently, the author (Pyke 1975b) has suggested that the ultramafic volcanic rocks in the Timmins area may have provided the main "source bed" for the gold which was subsequently mobilized. The mobilization occurred possibly in large part during carbonatization of the ultramafic rocks with subsequent deposition of gold in structurally favourable sites. W.O. Karvinen (1977) also favoured a model invoking carbonatization as an important factor, but favoured the quartz-feldspar porphyries as the source rock.

In addition to gold, abundant silver and minor scheelite have been won from the vein deposits.

A quartz-feldspar porphyry intrusion in Tisdale Township hosts a small porphyry copper deposit (8 million tons, grading 0.7 percent) which has been in production since 1960. Although copper mineralization has been noted in other porphyries in the area, these have not proven to be economically viable.

In 1973, production began from a nickel ore body along the east central boundary of the area in Langmuir Township. The mineralization is confined to ultramafic rocks at or near the base of the Tisdale Group. Mineralization consists mainly of pentlandite and lesser millerite; reserves were initially estimated at 1.8 million tons averaging 1.0 percent nickel (Panorama 1973).

Locally, the ultramafic rocks have been extensively replaced by magnesite; two large deposits are known, neither of which have been exploited.

Minor asbestos has been produced from the ultramafic sills in Deloro Township.

Early Precambrian (Archean)

METAVOLCANICS

On the basis of chemical composition, the metavolcanics in the Timmins area are divisible into three main subalkalic rock series:(1) komatiite, (2) tholeiite, and (3) calc-alkalic. The chemical variation between these three volcanic rock series is best illustrated on various ternary and binary plots. Those found to be the most useful in this regard are the AFM diagram (Irvine and Baragar 1971) using Na_2O + K_2O, FeO (total), MgO; the Jensen Cation plot (Jensen 1976) using Al_2O_3, FeO + Fe_2O_3 + TiO_2, MgO; and the binary plot introduced by N.T. Arndt (1975) of Al_2O_3 vs. FeO/FeO + MgO. Of these, the cation plot is particularly useful, it not only effectively discriminates rocks of the komatiitic suite, but in turn enables one to relate more readily to the chemical variations distinguishing komatiitic volcanic rocks from tholeiitic and calc-alkalic volcanic rocks. Figures 3a and 3b illustrate the two ternary plots with the respective komatiitic, tholeiitic, and calc-alkalic fields distinguished. Figure 3c also distinguishes komatiitic and tholeiitic fields, but in this classification, many of the Mg-tholeiites of Figure 3a are classified as basaltic komatiites. The pyroxenitic komatiites of Figure 3c correspond approximately to the basaltic komatiites of Figures 3a and 3b. In this classification (Figure 3c), tholeiitic volcanic rocks plot to the right of the inclined solid line. Figure 3d incorporates the data and terminology from Munro Township (Figure 4 from Arndt 1975) on to a cation plot, illustrating in particular the expanded komatiitic field. Notice the basaltic komatiites of Figure 3d incorporate all of the field of Mg-tholeiites in Figure 3b. Nevertheless, in this report, the field boundaries shown on the cation diagram by L.S. Jensen (1976) in Figure 3b are used for the volcanic rock classification, but it is recognized that many, if not most of those volcanic rocks which plot in the field of Mg-tholeiite may have komatiitic affinities. This will be particularly evident in the section of the report dealing with stratigraphy, as well as that on ultramafic intrusions. It has become evident from studying a much larger area than that of the Timmins area, that compositions designated either as Mg-tholeiite in Figure 3b or basaltic komatiite in Figures 3c or 3d can form part of a komatiitic, tholeiitic, or even a calc-alkalic volcanic suite.

Although the metavolcanics of a particular chemical composition are not wholly confined to any one group or formation, there is an overall trend reflecting a large scale cyclicity or differentiation pattern to the volcanism. For example, the Deloro Group, comprising the oldest volcanic rocks in the area, is largely calc-alkalic in composition, although minor tholeiites and komatiites occur at the base of the group. The base of the overlying Tisdale Group is composed mainly of komatiites; this in turn is overlain predominantly by a tholeiitic sequence, which in turn is capped by calc-alkalic volcanism.

The following treatise on the metavolcanics deals with the characteristics of a particular rock suite defined by the chemical composition as komatiitic, tholeiitic, or calc-alkalic, and does not imply a stratigraphic connotation. As mentioned above, the subdivision into the various volcanic suites follows those shown on the cation plot of Figure 3b.

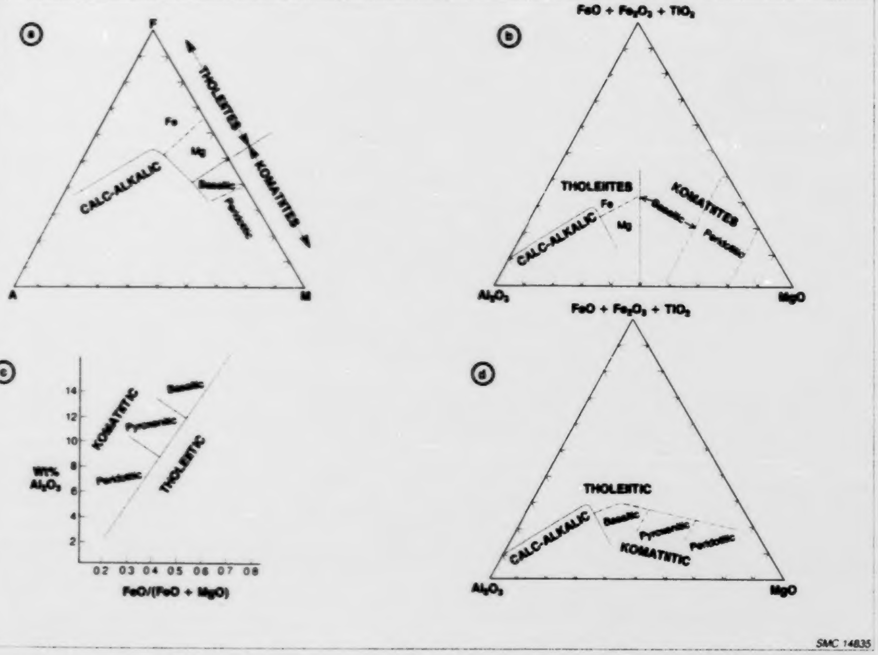

Figure 3a–AFM diagram (A = $Na_2O + K_2O$; F = FeO total); M = MgO). Calc-Alkalic boundary taken from Irvine and Baragar (1971). Tholeiitic and komatiitic fields correspond to compositions taken from Figure 3b. Oxides are in weight percent.

Figure 3b–Cation plot (after Jensen 1976); Al_2O_3- ($FeO + Fe_2O_3 + TiO_2$)-MgO in cation percentage (*see* Barth 1962). This plot forms the basis of the nomenclature used throughout report. For example, rocks shown to be of a particular calc-alkalic, tholeiitic, or komatiitic composition from the above cation ratio, are also symbolized as being of such a composition on all other figures, unless indicated otherwise.

Figure 3c–Al_2O_3 vs. FeO_T/FeO_T + MgO diagram, showing komatiitic and tholeiitic fields as distinguished by Arndt (1975).

Figure 3d–Cation plot on which the tholeiitic and komatiitic fields are taken from the data of Arndt (1975) shown in Figure 3c. The calc-alkalic field is taken from that of Jensen (1976) in Figure 3b.

Komatiitic Volcanic Rocks

Komatiite was a term first introduced by M.J. Viljoen and R.P. Viljoen (1969a,b, and c) and encompasses a unique suite of volcanic and associated intrusive rocks occurring in the Swaziland Sequence in the Barberton Mountainland area in South Africa. As compared to other basaltic rock types (tholeiitic and calc-alkalic), komatiites were characterized by a high Ca/Al ratio (>1), high MgO (>9 percent), and very low K_2O (generally $< 0.1 - 0.2$ percent). Subsequently, komatiites were soon recognized in other shield areas, notably Australia (Glikson 1971; Nesbitt 1971; McCall and Leishman 1970) and Canada (Brooks and Hart 1972, 1974; Pyke *et al.* 1973; Arndt 1975; Imreh 1974) and have proven to be of major importance in helping to understand the evolution of Early Precambrian volcanism. Peridotitic komatiites (Figure 3b) are only known to occur in Precambrian terranes (Brooks and Hart 1974), and only rare post Precambrian basaltic komatiites are known (Gale 1973).

The original definition of komatiite as proposed by Viljoen and Viljoen (1969a,b, and c) has been somewhat expanded by Brooks and Hart (1974) and Arndt (1975) wherein; 1) the Ca/Al ratio is not deemed as rigorous a parameter as initially proposed (as some rocks with obvious komatiitic affinities have Ca/Al ratios <1, 2) a low TiO_2 content (< 0.9 percent) is mandatory, and 3) for a given aluminum content, the iron to magnesium ratio is commonly lower for komatiites than for tholeiites (Figure 3c). All these criteria are incorporated in the chemical distinction of komatiites in the Timmins Area.

One of the most unique features of the komatiitic suite is the ultramafic to very mafic composition of the rocks as opposed to the tholeiitic and calc-alkalic suites which range from mafic to very felsic varieties.

PERIDOTITIC KOMATIITES

Peridotitic komatiites are represented almost entirely by metamorphosed ultramafic flows; very minor ultramafic tuffs are present. The ultramafic flows are almost wholly confined to the base of the Tisdale Group, which marks the onset of a second cycle of volcanism in the area. Very minor ultramafic flows also occur at what is interpreted to be the base of the Deloro Group in the southwest corner of the area.

The metavolcanics of peridotitic komatiite composition weather orange-brown to dark grey. Fresh surfaces are typically dark green to black and commonly have a somewhat bluish hue which is particularly diagnostic.

One feature common to nearly all the ultramafic flows is a peculiar type of fracturing or what has previously been termed polysuturing (Pyke 1975b), polygonal jointing (Pyke 1970), or polygonite (Arndt 1975); the term polysuturing is retained here. In this structure, the rock is fractured into a number of semi-equant polygons ranging in diameter from about 1 cm to 70 cm, and commonly is in the order of 2 to 20 cm. Superficially, the weathered surface bears some resemblance to mud-cracks, as the periphery of the polygons is outlined by a slightly elevated "lip" (Photo 5). Polysuturing, however, is pervasive throughout the flows and probably represents some type of cooling phenomena; perhaps related to an incipient pillow development (Photos 6 and 7). Definite pillows,

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Photo 5—Polysuturing in ultramafic flow (peridotitic komatiite). Superficial resemblance to "mud cracking", with slightly elevated "lip" at periphery of polygons.

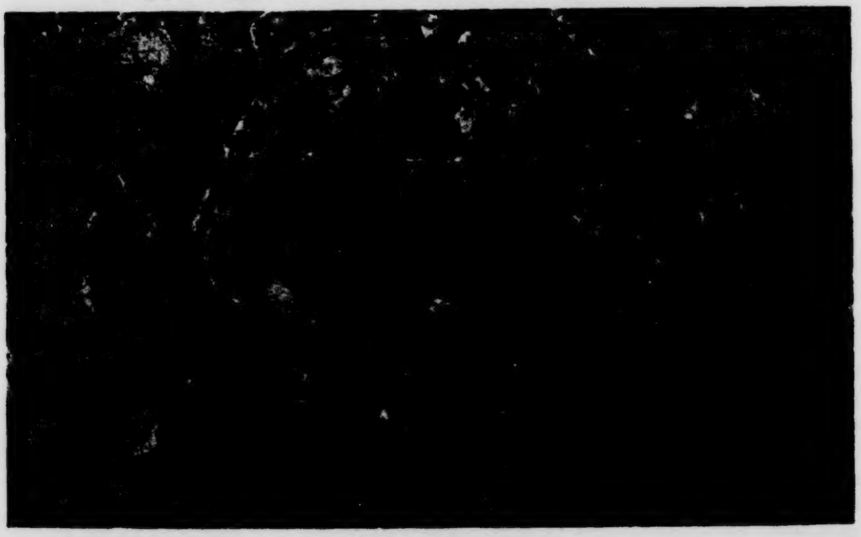

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Photo 6—Polysuturing in ultramafic volcanic flow (peridotite komatiite) in southwest Carman Township.

OGS 10 378

Photo 7–More polysuturing in ultramafic flow in southwest Carman Township. Suggestion of pillow development? Small polygons, approximately 3 cm below lens cap suggests presence of flow top. (Tops toward the top of photo).

however, were only seen at one outcrop. Where individual flows have been recognized, a tendency for the size of the polygons to decrease towards the top of the flow has been observed (Photos 7 and 8). Generally, however, individual flows are difficult to discern as polysuturing tends to obscure flow contacts. Arndt (1975) has suggested that extensive polysuturing is most likely to develop in the distal parts of flows where the viscosity is highest; a result of the ever increasing loss of heat and volatiles the further the lava is from its eruptive source. From the writer's observations, polysuturing is only found in those ultramafic rocks which can be demonstrated by means of flow contacts to be of extrusive origin; it is not found in intrusive ultramafic rocks which by comparison display a markedly regular joint pattern. Furthermore, polysuturing does not occur in other metavolcanics, other than some of the magnesium-rich basaltic komatiites in which it is generally not as well developed. It can therefore be a very useful structure in distinguishing ultramafic volcanic rocks which have been extensively metasomatized (Photo 8). For example, polysuturing is still evident in some of the sheared and extensively carbonatized volcanic rocks near the Destor-Porcupine Fault, thus distinguishing them as komatiites.

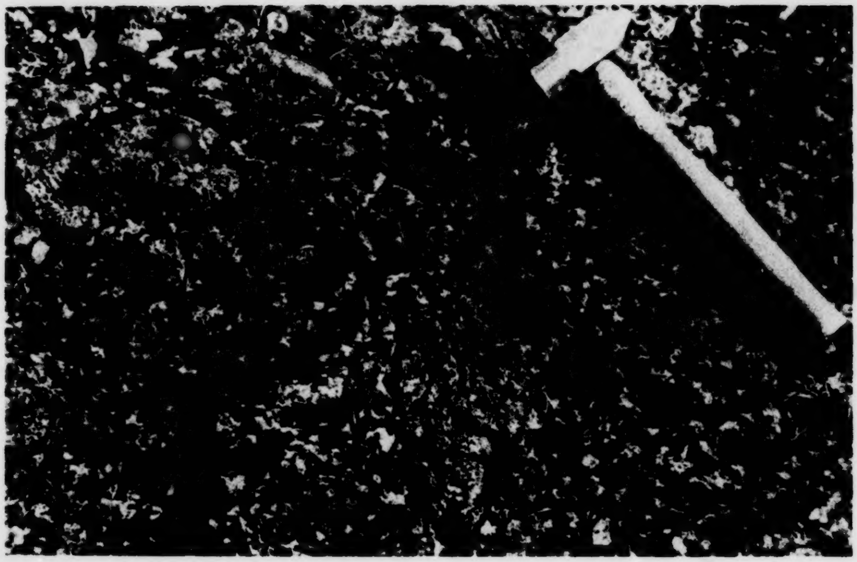

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Photo 8–Carbonatized ultramafic flow in which polysuturing preserved. Near Hallnor Mine, Whitney Township.

Individual flows are best observed in northwest Tisdale Township, concession V, lots 11, 12, although even here, extensive polysuturing makes it difficult to trace any one flow over a strike length of greater than 20 m. The flows vary from 1 to 4 m in thickness, are typically massive, and have a narrow 1 to 10 cm wide, chilled and fractured flow top. Some flows, with a spinifex-textured zone near the top, display all the internal structures (Figure 4) of the ultramafic flows described from Munro Township (Pyke *et al.* 1973). In southern Langmuir Township, some flows are no greater than 15 cm thick, and yet contain all the internal structures shown in Figure 4. However, outcrops are not well enough exposed to trace the thin flows more than a metre or two along strike. Nevertheless, it would be hard to conceive how such thin flows could be very extensive, for even though the lava would be very fluid on extrusion, rapid heat loss would quickly stagnate flowage.

Exposures of spinifex-textured flows (Photo 9) are most common in southern Langmuir Township. Here, as elsewhere in the area, the spinifex-textured part of the flows is not always readily identifiable as occurring at the top of the flow. Rather, some appears to occur as discontinuous lenses, pods, and stringers (Photo 10). This probably shows that isolated pockets of liquid became trapped within a largely crystalline flow.

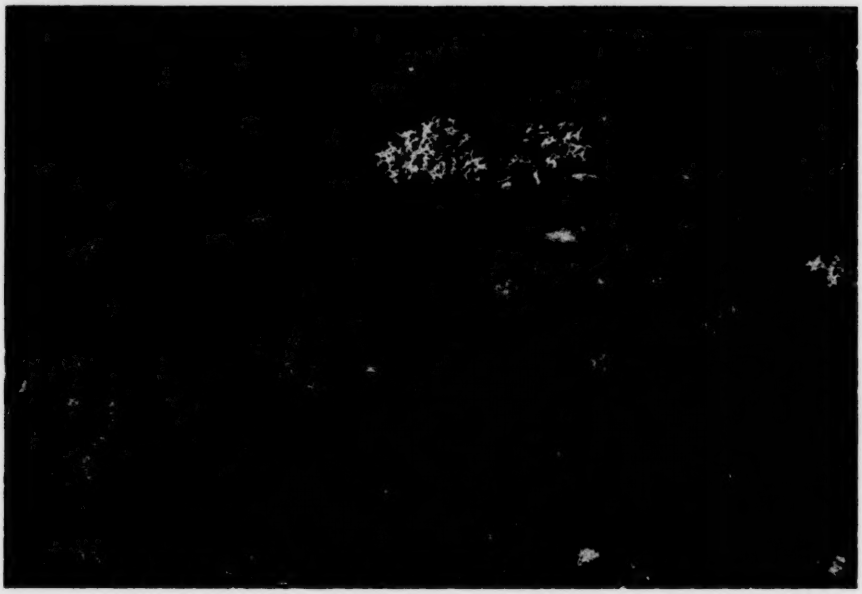

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Photo 9–Olivine spinifex in ultramafic flow in south Langmuir Township.

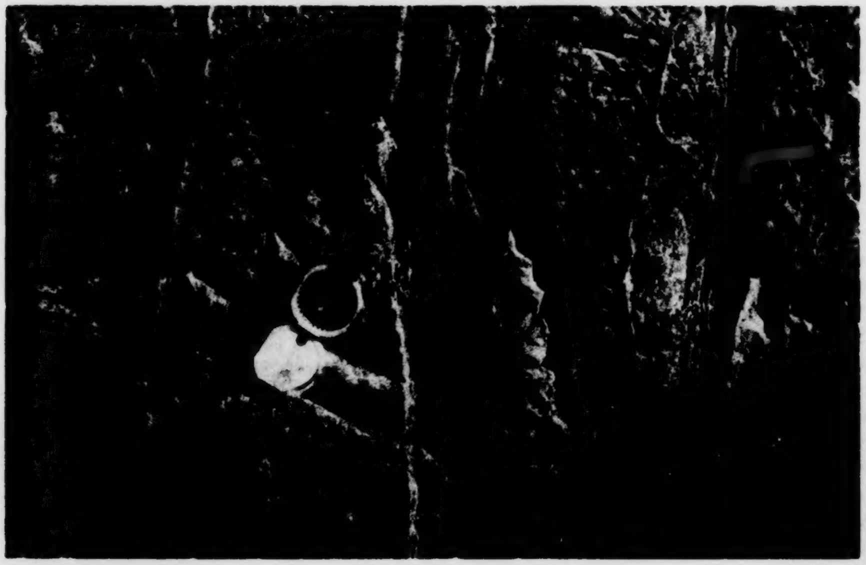

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Photo 10–Irregular stringers of spinifex in ultramafic flow.

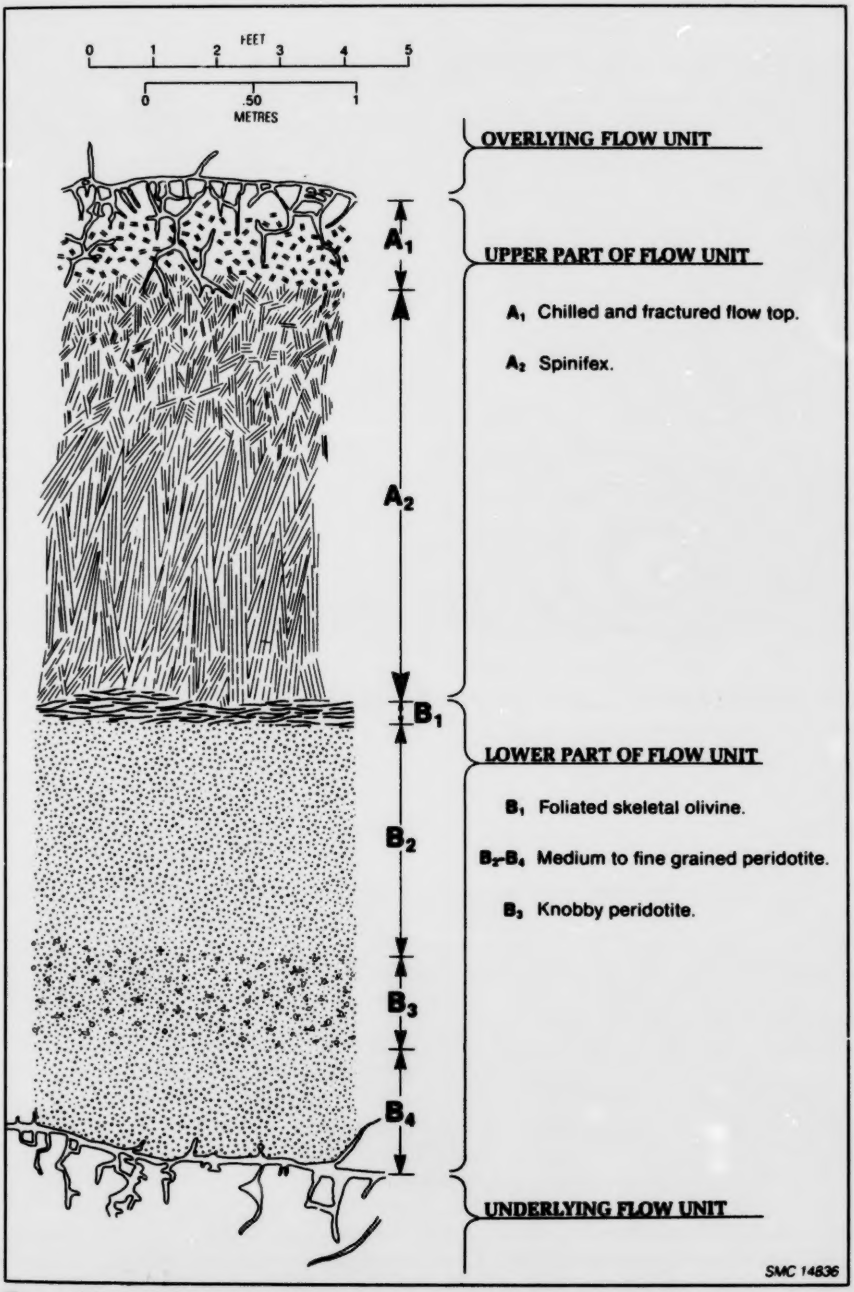
FEET
0 1 2 3 4 5
0 .50 1
METRES
OVERLYING FLOW UNIT
A1
UPPER PART OF FLOW UNIT
A1 Chilled and fractured flow top.
A2 Spinifex.
A2
B1
LOWER PART OF FLOW UNIT
B1 Foliated skeletal olivine.
B2-B4 Medium to fine grained peridotite.
B3 Knobby peridotite.
B2
B3
B4
UNDERLYING FLOW UNIT
SMC 14836

Figure 4–Diagrammatic section of an ultramafic flow (peridotitic komatiite) from Munro Township (after Pyke, Naldrett, and Eckstrand 1973).

OGS 10 382

Photo 11–Carbonatized olivine spinifex in ultramafic flow. Near Goose Lake in North Shaw Township.

The ultramafic flows are largely altered to serpentine, lesser amounts of tremolite and chlorite, and minor talc and carbonate. Up to 20 percent relict olivine is present in some of the non-spinifex textured flows or B zones (Figure 4) of the ultramafic metavolcanics in southern Langmuir Township. Elsewhere in the area 3 to 5 percent olivine is common. In the spinifex-textured parts of flows, former olivine blades consist of serpentine, lesser chlorite and minor magnetite. The blades are generally less than 1.0 mm thick, and are commonly 0.2 to 0.3 mm thick. Some olivine blades, which in outcrop appear to be as much as 60 to 100 cm in length, are seen in thin section to result from the stacking of several elongate crystals which can be up to 1 to 2 cm in length, either end to end, or in a somewhat *en-echelon* manner. Interblade areas are of a comparable size to the olivine blades and are composed mainly of tremolite and chlorite, that formed from the alteration of clinopyroxene and glass. Most magnetite and chromite is confined to the interblade areas, and forms very irregular to cruciform-shaped grains (Photo 12) similar to those described by Nesbitt (1971).

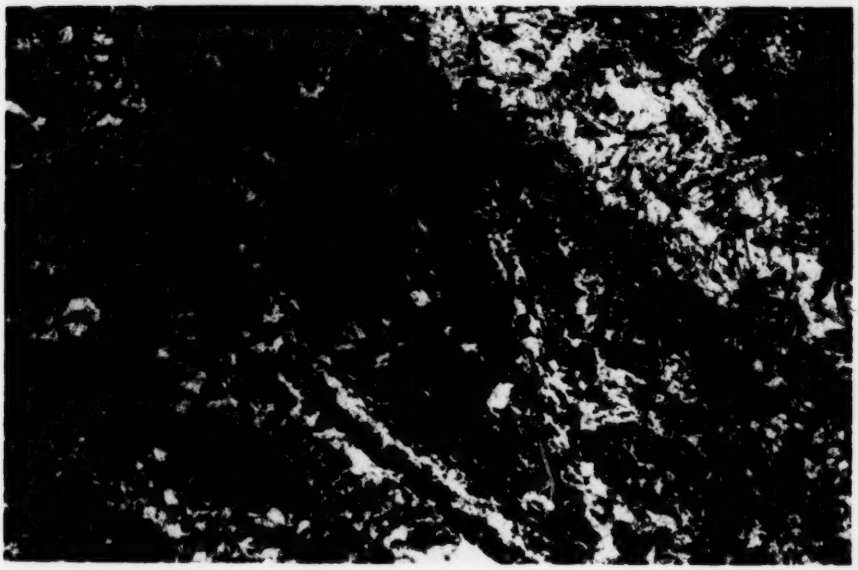

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Photo 12–Photomicrograph of cruciform-shaped chromite in interblade area of olivine spinifex-textured peridotitic komatiite. Sample P35-69.

Carbonatization

Many of the komatiitic volcanic rocks are highly altered to carbonate minerals. The peridotitic komatiites appear to be particularly susceptible to carbonate replacement as compared to other rock types. Commonly other volcanic rocks are only weakly to moderately carbonatized, although they are interlayered with ultramafic flows virtually completely altered to carbonate.

Carbonatization does not destroy spinifex-texture (*see* Photo 11) or polysuturing (*see* Photo 8) both of which serve in the field to readily identify the rocks as being altered ultramafic flows. The preservation of these textures would tend to support the view (Naldrett 1966) that there is negligible change in volume accompanying the alteration.

A simplified equation for the alteration reaction might be:

$6Mg_2SiO_4 + 2Ca_2(MgFe)\,Si_4O_{12} + 3H_2O + 14CO_2 \rightleftharpoons$

Olivine **Diopside**

$6MgCo_3 + Mg_3SiO_4\,(OH)_2 + H_4Mg_3Si_2O_9 + 4CaMg\,(CO_3)_2 +$

Magnesite **Talc** **Serpentine** **Dolomite**

$11SiO_2$

Quartz

The major elemental loss during carbonatization would appear to be on a proportional basis. When the analyses are recalculated to 100 percent (volatile free), the composition is similar to serpentinized varieties, and to the relatively unaltered ultramafic flows found in Munro Township.

The carbonate mineralogy of the altered samples was identified by using staining techniques as outlined by W.P. Reid (1969), supplemented by X-ray diffraction determinations, and where available partial or whole rock chemical analyses of the rocks. None of the above three methods (staining, XRD, or chemical analysis) offer an unequivocal determination of the carbonate mineralogy. Nevertheless, a combination of the three independent methods should give a reasonable estimate of the proportions of the various carbonate minerals present. The carbonatized flows contain 20 to 50 percent magnesite, 10 to 40 percent dolomite, 2 to 15 percent talc, 8 to 15 percent quartz, and minor serpentine, chlorite, magnetite, and chromite.

Basaltic Komatiites

Basaltic komatiites are almost wholly confined to the lower part of the Tisdale Group. The flows vary from 5 to 100 m in thickness, and are on average approximately 30 to 45 m thick. The upper one-third to one half of the flows are generally pillowed; individual pillows are ellipsoidal in shape, range from 0.5 to 2 m in maximum dimension, and average approximately 1 m. Some flows contain a narrow zone, 30 to 100 cm thick, of pyroxene spinifex (Photos 13 and 14) at the top, which in some outcrops was seen to be capped by a narrow, 50 cm thick, flow top breccia consisting largely of fragments of basaltic komatiite and minor cherty rhyolitic-appearing volcanic rocks. One flow in southwest Carman Township is about 20 m thick, the upper 15 m of which consists of two juxtaposed zones of pyroxene spinifex, both grading from fine-grained randomly oriented pyroxene spinifex at the bottom to string-beef type spinifex (Arndt 1975) at the top. There is no apparent flow contact between the two spinifex zones, rather there is a narrow (10 cm) zone of pyroxene spinifex in which acicular-shaped pyroxene crystals are oriented parallel to the flow contacts.

Some of the pillowed parts of flows contain minor vesicules. Variolites are locally common, and pillow breccias are rare. The magnesium-rich basaltic komatiites are easily recognized in the field because they are light grey to light

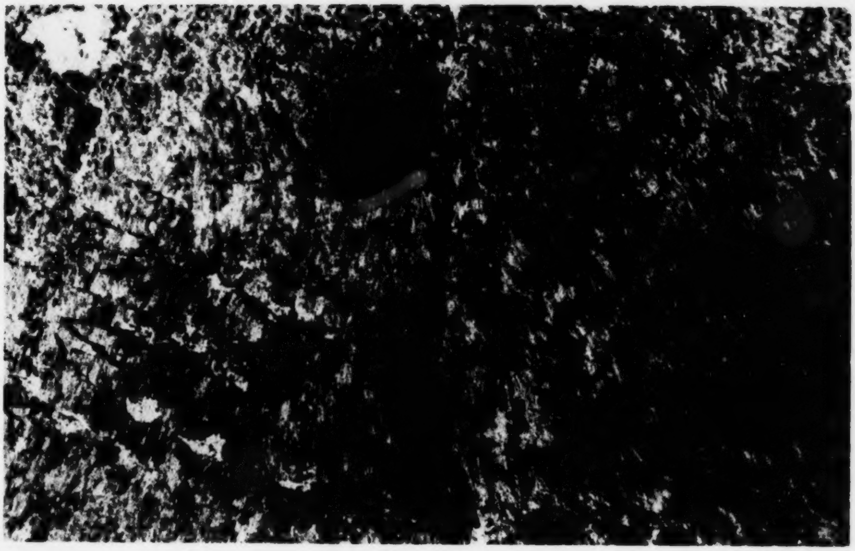

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Photo 13–Pyroxene spinifex in basaltic komatiite, southwest Carman Township.

greenish grey and are notably softer (more easily scratched) than tholeiitic basalts. In the basal coarse-grained massive parts of flows, densely packed tremolitic splays are readily discernable in hand specimen. The rocks take on a darker hue as serpentine becomes prominent in the transition zone from basaltic to peridotitic komatiites. Weathered surfaces are medium grey to light orange-brown, and the magnesium- rich varieties show a poor development of polysuturing.

Tremolite is the dominant constituent of the basaltic komatiites, forming 70 to 90 percent by volume of the rock. In thin section, the tremolite is seen to occur either as a dense felted mass or a plumose -type texture (Photo 15) in which equant splays of tremolite average approximately 3 mm in the coarse parts of flows. A suggestion of a skeletal texture, after clinopyroxene, is locally preserved. The magnesium-rich varieties contain up to 25 percent by volume of serpentine, some of which is pseudomorphous after skeletal blades of olivine up to 5 mm in length. Minor chlorite and traces of opaque minerals are generally the only other constituents present. In the transition zone from komatiitic to tholeiitic volcanic rocks, minor (5 to 10 percent) plagioclase appears, which is completely altered to an extremely fine-grained light brown coloured matte of predominantly clinozoisite and minor epidote.

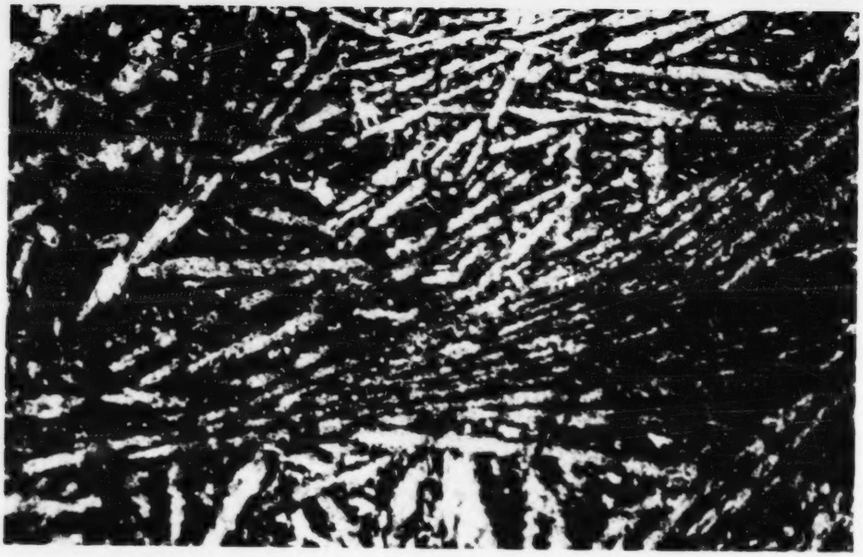

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Photo 14–Photomicrograph of pyroxene spinifex in basaltic komatiite. Sample P632-75.

OGS 10 386

Photo 15–Photomicrograph of basaltic komatiite consisting almost entirely of tremolite and less than 10 percent saussuritized plagioclase. Sample P500-73.

Pillowed parts of basaltic komatiite flows are commonly variolitic; varioles range from less than 1 mm to 5 mm in diameter. In thin section, the varioles are seen to consist of crudely radiating plagioclase and minor tremolite, and are set within a matrix of colourless chlorite.

Chemistry and Classification of the Komatiitic Suite

Chemically, the metavolcanics of the komatiitic suite form an unique rock association which varies in composition from ultramafic to mafic. Magnesium shows the greatest change throughout the suite, varying from approximately 19 to 42 percent in the peridotitic komatiites, and 10 to 19 percent in the basaltic komatiites. The major components SiO_2, Al_2O_3, FeO (total), and CaO average about 45 percent, 5 percent, 10 percent, and 8 percent respectively in the peridotitic komatiites, and 47 percent, 8 percent, 12 percent, and 11 percent respectively in the basaltic komatiites.

All the chemical analyses of peridotitic komatiites and basaltic komatiites from the Timmins area are given in Tables I, II, XI, XIV and XVIII (in back pocket, on microfiche). There is a preponderance of analyses of peridotitic komatiites recorded, because many of these analyses are taken from a thesis by T.L. Muir (1975). In these, only five major oxides were determined, and these are also listed separately in Tables XI, XIV, and XVII, (in back pocket). T.L. Muir (1975) in his treatise of the ultramafic rocks, devised a discriminant function which could be applied to the chemical analyses to discriminate between intrusive and extrusive ultramafic rocks. This is especially applicable to diamond-drill core samples where it is more difficult to discern primary textures and structures often so evident on the weathered surfaces of outcrops. Parameters for the discriminant function were derived, on the basis of field and petrographic criteria, from known extrusive and intrusive ultramafic rocks. Questionable intrusive - extrusive ultramafic rocks were assigned to one or the other category by means of the discriminant.

Statistically, this was done for both the 90 and 66 percent confidence limits. Therefore, in the analyses taken from Muir (1975), the samples are listed either as confirmed, classification from field or petrographic criteria, or unconfirmed, classification on the basis of discriminant function analysis.

The oxides most commonly used to differentiate the komatiitic suite are CaO, MgO, Al_2O_3, ($FeO + Fe_2O_3$) and TiO_2. These oxides are used in a number of plots in Figures 5a, 5b,5c, 6a, and 6b.

The CaO, MgO, Al_2O_3 ternary diagram was originally used by Viljoen and Viljoen (1969a and b) to differentiate the various komatiitic rocks in the Barberton area. A plot of this type (Figure 5a) for the Timmins area shows the Ca/Al ratio remains fairly constant between one and two, thus meeting one of the main requirements set forth by Viljoen and Viljoen (1969a and b) of komatiite. In the Timmins area, the komatiitic rocks have only been divided into peridotitic and basaltic varieties. Viljoen and Viljoen (1969a and b) subdivided the komatiites into four types. The peridotitic field is one, and a basaltic field contains other three types, the Badplass, Geluk, and Barberton; these subdivisions are shown for comparison on Figure 5b.

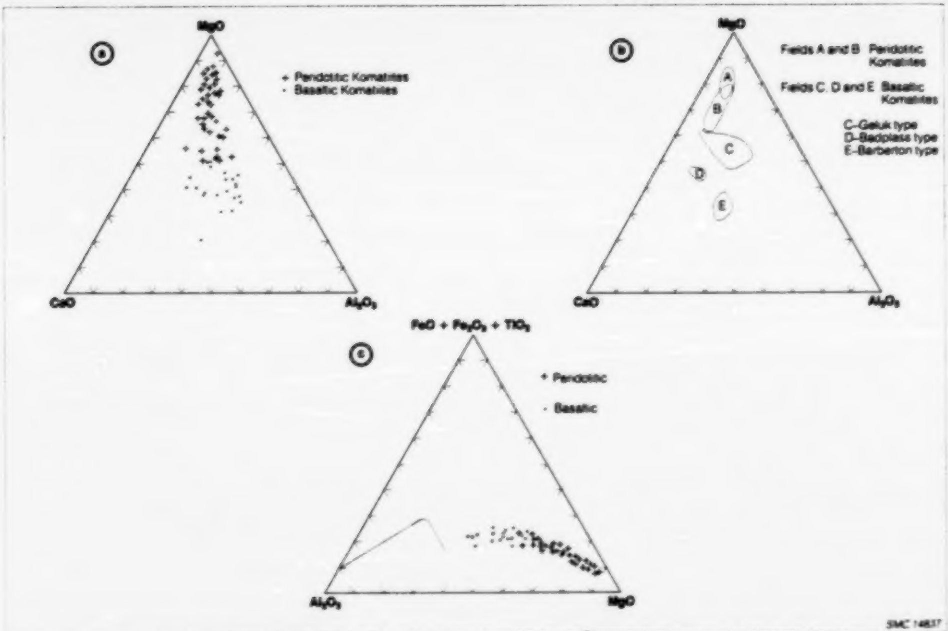

Figure 5a–MgO-CaO-Al_2O_3 diagram of the peridotitic and basaltic komatiites from the Timmins area. Analyses from Tables I and II only.

Figure 5b–CaO-MgO-Al_{2O3} diagram showing the fields of peridotitic and basaltic komatiites from the Barberton area (Viljoen and Viljoen 1969a and b).

Figure 5c–Cation plot (Al_2O_3 - (FeO + Fe_2O_3 + TiO_2) - MgO) of peridotitic and basaltic komatiites from the Timmins Area.

Figure 5c is a ternary plot of the cation percentage of Al_2O_3 - FeO + (Fe_2O_3 + TiO_2) - MgO as devised by Jensen (1976). This illustrates very well the spread in compositions between peridotitic and basaltic komatiites, and the relation to the tholeiitic and calc-alkalic fields. In this plot, it is seen that the Al/Fe + Ti ratio remains relatively constant at about 0.5 to 1 throughout the peridotitic komatiite field, and with differentiation, the compositions move steadily away from the MgO apex, largely reflecting the removal of olivine. In the basaltic komatiite field, the ratio increases as the crystallization of pyroxene dominates, and finally, plagioclase appears near the tholeiite-komatiite boundary. In general, the Fe/Mg ratio is less than 2 to 1 in the peridotitic komatiites and between 1 and 2 to 1 in the basaltic komatiites. This largely reflects a change in the MgO content as iron remains relatively constant throughout the komatiitic field. The variation in the Fe:Mg ratio is perhaps best illustrated on an AFM diagram (see Figure 3a), yet at the same time, the komatiitic field does not show the same spread in compositions by using alkalies as opposed to Al in the cation plot.

Arndt (1975) introduced a binary plot to chemically distinguish various komatiitic rocks, and at the same time discriminate between the tholeiitic and komatiitic series. This plot features Al_2O_3 on the absicca and FeO/FeO + MgO on the ordinate (Figure 6a). Arndt originally devised a five-fold classification of komatiites; 1) peridotitic komatiites (MgO, more than 30 percent); 2) pyroxene peridotitic komatiite (MgO, between 30 and 20 percent); 3) pyroxenitic komatiite (MgO, between 20 and 12 percent); 4) basaltic komatiite (MgO, 12 percent); 5) andesitic komatiite (SiO_2 about 54 percent). The andesitic komatiites are as yet an ill-defined group (Arndt 1975). This classification scheme is supported by abundant field criteria and chemical analyses from an extremely well exposed and preserved section of komatiitic rocks in Munro Township. The nomenclature was subsequently modified (Arndt *et al.* 1977) and three types of komatiites were recognized; these are peridotitic, pyroxenitic, and basaltic, as shown in Figure 6a. For comparison, the data of Figure 6a are shown on the cation diagram of Figure 6b, and it is readily seen that the field of basaltic komatiite on Figures 6a and 6b incorporates the Mg-tholeiitic field of the cation plot (see Figure 3b) and that pyroxenite komatiites (Figure 6b) correspond to basaltic komatiites (see Figure 3b). At present, it is difficult if not impossible to separate the fields of Mg - tholeiite (see Figure 3b) and basaltic komatiite (Figure 3d) on the basis of major element chemistry alone. Nevertheless, there can be little doubt that rocks of this composition (those which plot in the Mg-tholeiite field of Figure 3b) which have traditionally been termed tholeiites (Irvine and Baragar 1971; Yoder and Tilley 1962) may in many instances have a komatiitic affinity. That this is so, has been shown by Arndt (1975) and Arndt *et al.* (1977) where individual differentiated flows and sills range in composition from peridotitic komatiites to the Mg - tholeiites of Figure 3b, or the basaltic komatiites of Figure 3d. Similarly, pyroxenitic and gabbroic differentiates of dunites at the periphery of the Shaw Dome have compositions spanning the pyroxenitic and basaltic komatiite field of Figures 6b and 3d.

An important feature noted by Arndt (1975) is that the plot in Figure 6a effectively discriminates between cumulates of tholeiitic or komatiitic derivation.

Tholeiitic Volcanic Rocks

The tholeiitic metavolcanics are subdivided into two main groups: (1) magnesium-rich tholeiites (Mg-tholeiites) and (2) iron-rich tholeiites (Fe-tholeiites). The tholeiitic metavolcanics are largely confined to the Tisdale Group, although some are intercalated with the metavolcanics of the Deloro Group. Even though there is a continuum in compositions between Mg- and Fe-tholeiites, it is generally possible to assign most of the tholeiitic volcanic rocks to one or other category during routine field mapping.

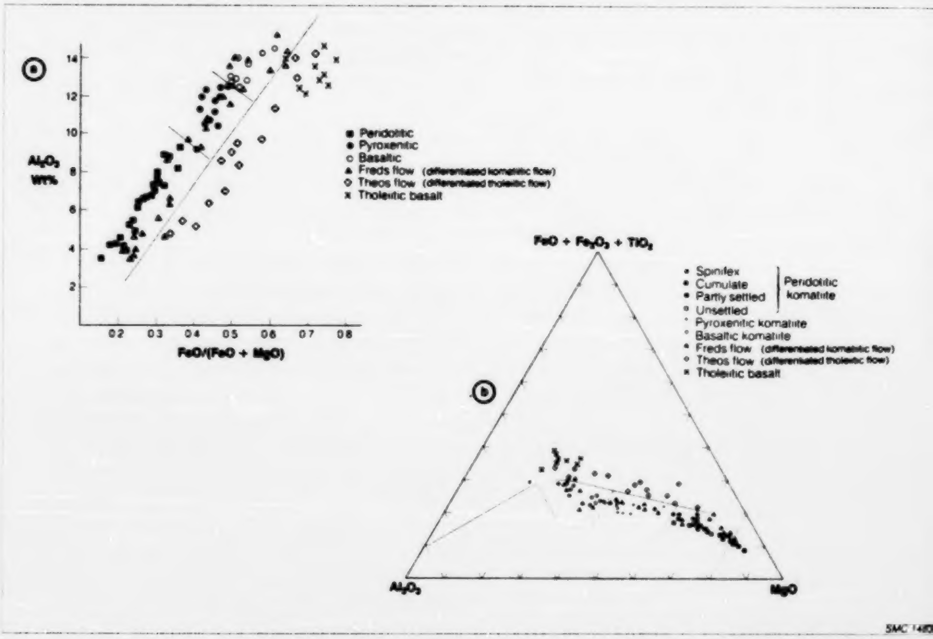

Figure 6a–Al_2O_3 vs. FeO_T/FeO_T + MgO diagram of komatiitic and tholeiitic volcanic rocks in Munro Township (Arndt 1975).

Figure 6b–Cation diagram (Al_2O_3 - ($FeO + Fe_2O_3 + TiO_2$) - MgO) showing distribution of komatiitic and tholeiitic volcanic rocks from Munro Township. Analyses, and komatiitic and tholeiitic subdivisions from Arndt (1975); calc-alkalic boundary are from Jensen (1976).

MAGNESIUM THOLEIITES

Metavolcanics of magnesium, tholeiite composition (Mg-tholeiites) are typically light grey to light green, and weather medium grey to greenish grey. Flows vary from approximately 10 to 150 m in thickness and are commonly up to 60 m thick. Grain size varies from a fraction of a millimetre in the upper parts of flows, to 3 to 4 mm in the basal parts. Pillowed flow tops are common, forming the upper one-half to one-third of a flow. Some flows appear to be pillowed throughout, perhaps indicative of the more distal part of the flow. Pillow breccias (Photo 16) are common at the tops of flows. Isolated and broken pillows are set in a matrix of hyaloclastite. This in turn may grade upward into flow tops consisting almost entirely of hyaloclastitic material with only a few recognizable broken pillow fragments.

OGS 10 387

Photo 16–Pillow breccia in Mg-tholeiitic basalt on Simpson Lake, Tisdale Township.

The light grey-green colour of the fresh surface can make it difficult in the field to distinguish between Mg-tholeiitic volcanic rocks and calc-alkalic basalt-andesite. Commonly in the Timmins area, however, the local stratigraphy will give an indication about the chemical affinity of a rock; Mg-tholeiites are interlayered with basaltic or peridotitic komatiites or Fe-tholeiites, whereas these are uncommon associations with the calc-alkalic volcanic rocks. There is, however, minor local intercalation of calc-alkalic and komatiitic volcanic rocks at the interface of the Deloro and Tisdale Groups.

Thin section examination reveals that the Mg-tholeiitic metavolcanics contain 15 to 50 percent plagioclase (average 30 to 40 percent), 80 to 40 percent actinolite-tremolite (average 50 to 60 percent), 2 to 5 percent quartz, accessory sphene and opaque minerals, and minor secondary chlorite and traces of sericite. The plagioclase is virtually completely saussuritized consisting of a dull brown semi-birefringent matte in which epidote, clinozoisite, and minor albitic plagioclase is discernable. A very pale green non-pleochroic actinolitic hornblende is the dominant mafic constituent as compared to tremolite in the basaltic komatiites. It is the sudden increase in the volume percent of plagioclase which is the most notable petrographic difference between the Mg-tholeiites and basaltic komatiites. In addition, the pale coloured low-Fe-bearing actinolite aides in distinguishing the Mg-tholeiites from the more strongly coloured

Fe-rich actinolite and hornblende of the Fe-tholeiitic metavolcanics. The flows are equigranular, the grain size varies approximately from 1 to 5 mm in the massive lower parts to 0.25 to 1 mm in the pillowed parts.

IRON THOLEIITES

With an increase in the Fe/Mg ratio, the Mg-tholeiites grade into the Fe-tholeiites. The metavolcanics of Fe tholeiitic composition are medium to dark green or black, and weather medium to dark grey, or dark green. The black varieties are almost invariably magnetic, and readily attract a hand magnet. In contrast, neither the mafic calc-alkalic basalts nor the Mg-tholeiitic basalts are magnetic. Individual flows are commonly 30 to 45 m thick and range from approximately 10 to 160 m in thickness; the thickest flows were observed in north Douglas Township.

In thin section, the mafic component is seen to be largely a weakly pleochroic light to medium green actinolitic hornblende, or pleochroic light brown to medium green hornblende. Hornblende, however, appears to be confined to the tholeiitic metavolcanics in the southeastern part of the area, whereas an actinolitic amphibole characterizes the mineral assemblages elsewhere in the area. None of the original plagioclase remains because saussuritization and chloritization are pervasive. In some flows, secondary albitic plagioclase forms sympletitic intergrowths with quartz; this is particularly common of the 99 flow in Tisdale Township (Ferguson *et al.* 1968). Quartz is common to all the flows, forming 3 to 12 percent by volume. Titaniferous magnetite, partly altered to leucoxene, and magnetite are common (2 to 5 percent by volume) accessories in many of the Fe-tholeiites. Grain size varies from less than 1 mm to 5 mm.

Variolitic basalt forms part of the Fe-tholeiitic volcanic succession, and is largely confined to that part of the area north of the Destor-Porcupine Fault; in particular to two main sequences of flows which have been termed the V8 and V10 respectively (Ferguson *et al.* 1968). Both flow types have pillowed upper parts and massive basal sections. Commonly, the pillows are unusually large, rare occurrences having been reported up to 3 by 10 m; generally, however, the pillows are in the order of 1 by 2 m. The varioles are light grey, and may either be concentrated at the margins or central parts of the pillows, or dispersed throughout the pillows. Individual varioles range from approximately 2 mm to 3 cm in diameter and average less than 1 cm. In at least a part of what has been termed the V10 flows (Ferguson *et al.* 1968), volcanic rock of the composition of the varioles dominates the central part of the pillows (Photo 17). Only at the margins of the pillows are individual light grey weathering varioles discerned within a dark green matrix. In this case, the dominant composition of the pillows is that of the varioles. In contrast, pillows in the V8 flow (Ferguson *et al.* 1968) generally consist dominantly of the dark green basaltic matrix. In thin section, it is seen that most varioles are composed primarily of plagioclase, which may or may not possess an obvious radiating texture. In many varioles, plagioclase is saussuritized or partly carbonatized. In some, plagioclase incorporates semi-radiating clusters of elongate hornblende needles (length to width

OGS 10 388

Photo 17–Variolitic pillow basalt (V10) in which varioles have largely coalesced in central part of pillow. Outcrop at fire tower in Tisdale Township.

ratios of 30 to one); in others, perlitic fractures dominate (Photo 18). The matrix for the variolites consists of varying proportions of very pale green actinolite, chlorite, and epidote-clinozoisite. Also interlayered with the variolitic basalts is a very distinctive variolitic-bearing rock in which the texture is locally referred to as "chicken feed" (Ferguson *et al.* 1968). Where observed by the author, this consisted mainly of broken up varioles in a hyaloclastite and pillow breccia matrix. Locally, the flow passes into nonfragmented variolitic pillow basalt.

In some pillowed parts of flows, vesicles are common, and are concentrated near the upper margins of the pillows (Photo 19).

OGS 10 389

Photo 18–Photomicrograph of perlitic fractures in variolite. Sample P1237-75.

OGS 10 390

Photo 19–Vesicles concentrated along the upper rim of pillows in tholeiitic basalt Tisdale Township.

CHEMISTRY OF THE THOLEIITIC VOLCANIC ROCKS

The tholeiitic metavolcanics in this report are subdivided into Fe-rich and Mg-rich types on the basis of the cation plot (see Figure 3b) of L.S. Jensen (1976). As the change in composition from Fe- to Mg-tholeiiitic volcanic rocks is a continuum, there is necessarily an uncertainty in composition between the two fields; this uncertainty is of course caused by placing any boundary in a continuum, as well as the analytical uncertainties. The main compositional overlap is in the triangular area marked X in Figure 7a. In any event, it (the x) does serve to illustrate a somewhat intermediate composition between the Fe- and Mg-tholeiites, which in parts of the area appears to have a stratigraphic significance.

Most Mg-tholeiitic volcanic rocks contain between 6 and 10 percent MgO, and most contain greater than 7 percent. Iron (Fe0 Total) varies from about 8 to 11 percent. In contrast, most Fe-tholeiitic volcanic rocks contain less than 7 percent MgO and FeO (Total) varies from about 11 to 19 percent. There is minor overlap in the Fe-Mg values, but in general, the Mg-tholeiites have Fe/Mg ratios varying from 1:1 to 2:1, whereas in the Fe-tholeiites the Fe/Mg ratio is greater than 2:1. At Fe/Mg ratios less than 1:1, Mg-tholeiites grade into basaltic komatiites. The Al_2O_3 values differ somewhat; 14-17 percent in the Mg-tholeiites and 12-14 percent in the Fe-tholeiites. Titanium serves as an important indicator, in that TiO_2 is generally less than 1.0 percent in the Mg-tholeiites and greater than 1.0 percent in the Fe-tholeiites (Figure 7b).

On a CaO, MgO, Al_2O_3 plot (Figure 7c), the tholeiites form a relatively distinct field separate from the komatiites, but show considerable overlap with the calc-alkaline field. The plot, however, roughly distinguishes between Mg- and Fe-tholeiitic volcanic rocks.

Calc-Alkalic Metavolcanics

Metavolcanics of calc-alkaline chemical affinity are almost wholly confined to that part of the Deloro Group within the Shaw Dome, centred in Shaw Township in the east-central part of the area. Here, the calc-alkalic metavolcanics range in composition from basalt to rhyolite; basalt-andesite compositions dominate. Subordinate calc-alkalic volcanic rocks, generally of a dacitic composition, occur north of the Shaw Dome in the vicinity of the main gold camp. In the northwestern part of the area, minor calc-alkalic volcanic rocks extend into the Timmins area; these form the eastern extremity of a thick succession of calc-alkaline metavolcanics in the Kamiskotia area (Middleton 1975).

The following discussion of the calc-alkalic volcanic rocks deals mainly with the Deloro Group of the Shaw Dome area. When discussion centres on other areas, specific reference is made to these.

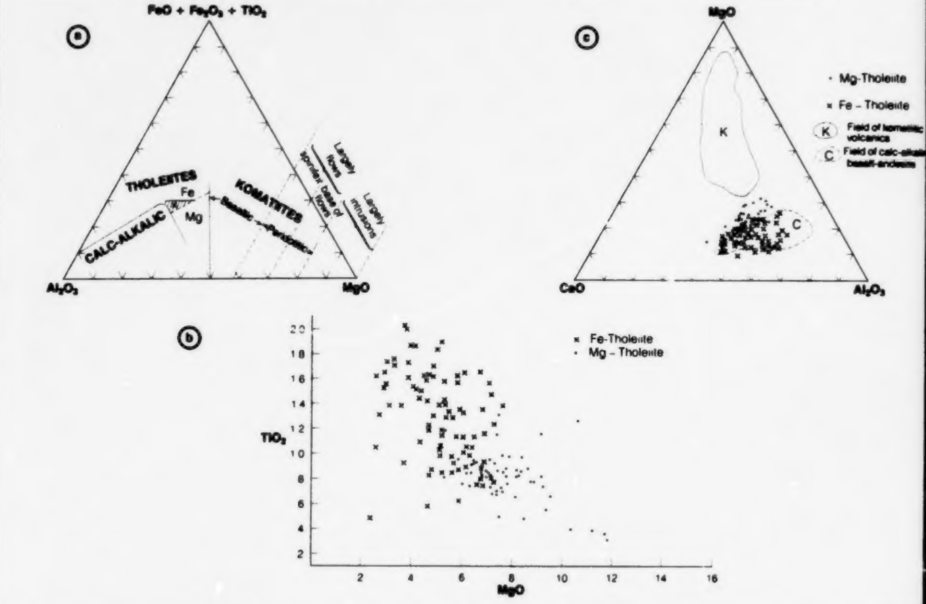

Figure 7a–Jensen cation diagram (Al_2O_3 -FeO + Fe_2O_3 + TiO_2) - MgO) Compositions intermediate between Mg and Fe-tholeiite are marked by X.

Figure 7b–TiO_2 vs MgO diagram for iron (Fe) and Magnesium (Mg) tholeiitic basalts.

Figure 7c–CaO-MgO-Al_2O_3 diagram showing distribution of iron (Fe) and magnesium (Mg) tholeiitic volcanic rocks. The field of komatiitic volcanic rocks as taken from Figure 5a, is outlined with solid line. Mafic (basalt-andesite) calc-alkaline volcanic rocks, field outlined in dashed line, show considerable overlap with the tholeiitic volcanic rocks, particularly the Fe-tholeiites.

MAFIC CALC-ALKALIC METAVOLCANICS

Calc-alkalic basalt and andesite underlie much of the Shaw Dome (*see* Figure 2) and forms the major part of the Deloro Group. There is little if any distinction possible in the field between andesite and basalt, and not uncommonly, some dacites are readily mistaken for the more basaltic end members. The basaltic-andesitic metavolcanics vary from light grey to medium dark green, and weather medium to dark green or buff. The majority of the flows are pillowed; individual pillows are commonly in the order of 0.5 by 1.5 m in size. Rare exposures of pillows in three dimensions showed some to be elongated and to have a tube-like morphology. As with many pillowed volcanics, however, it is

OGS 10 391

Photo 20–Concentric cooling cracks in pillowed calc-alkaline andesite. Sample P269-73. Abundant pillow breccia. Outcrop in gravel pit adjacent to Langmuir Mine road in Shaw Township.

generally difficult to know exactly what section one is observing on the outcrop surface. Therefore, it is difficult to visualize a three dimensional configuration of the pillows. Some exceedingly large pillows are associated with the flows in east-central Shaw Township. One of the best exposures is in a gravel pit adjacent to the Langmuir Mine road about 3.5 km from the Whitney-Shaw township boundary. Here, some pillows have maximum exposed dimensions of 9 m by 4.5 m. Narrow cooling cracks (Photo 20), spaced at about 1 cm intervals, parallel the rim of the pillows and form a concentric zone extending from the margin to half the distance to the centre of the pillow. Minor hyaloclastite and broken pillow breccia (Photo 20) is interstitial to the pillows, and is a common feature of other calc-alkalic flows in the vicinity. Other pillows display radial and concentric fracturing (Photo 21).

Many of the flows are amygdaloidal; quartz, calcite, and less chlorite form the main amygdule fillings.

The calc-alkalic basalts and andesites are typically porphyritic (Photo 22) with subhedral, twinned phenocrysts of plagioclase, averaging 0.2 to 0.3 mm in length, and varying from 15 to 65 percent by volume, set in a fine-grained (0.25 mm) matrix of non-twinned anhedral plagioclase, chlorite, pale green actinolite, and quartz (as much as 10 percent). Minor quartz also occurs as phenocrysts comparable in size to the plagioclase. The plagioclase phenocrysts are albite to

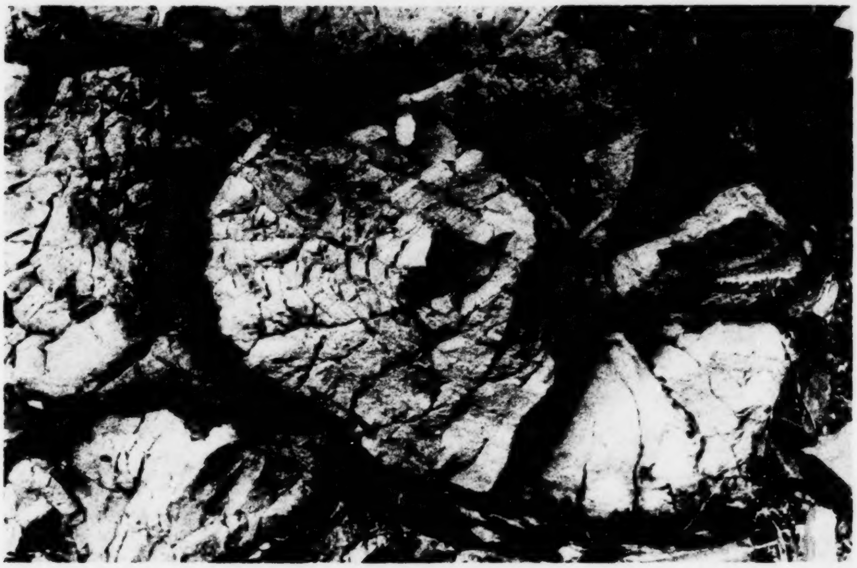

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Photo 21–Radial fractures in pillow in calc-alkalic basalt northeast Whitney Township.

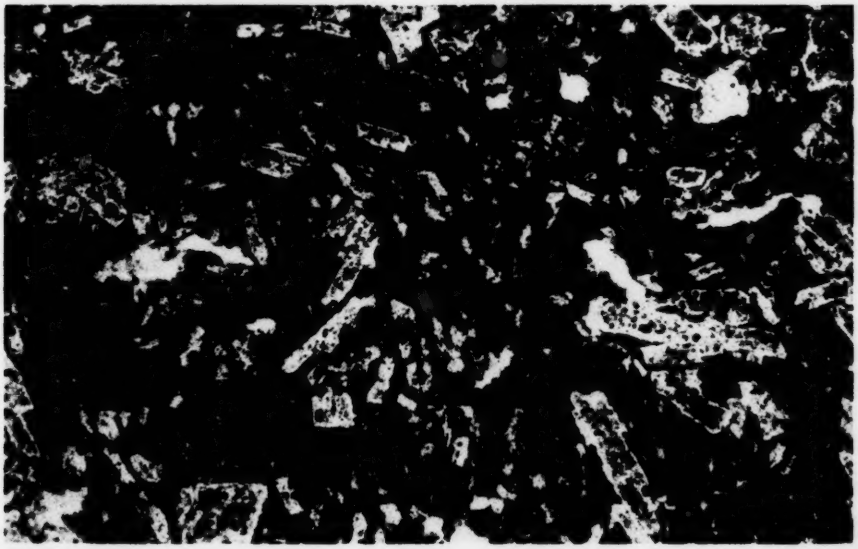

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Photo 22–Photomicrograph of calc-alkaline andesite-basalt. Notice abundance of plagioclase phenocrysts.

sodic oligoclase in composition, and only show minor alteration to white mica, epidote, and lesser calcite. The plagioclase in the matrix is more highly altered and associated with chlorite. Epidote and clinozoisite are common, forming 3 to 15 percent by volume of the rocks. Accessory minerals include traces of opaques, sphene, leucoxene, and apatite. The original colour index is difficult to estimate as it is not obvious what proportion of the chlorite was derived from mafic minerals versus plagioclase. Nevertheless, many appear to have a colour index in the order of 35 percent. With increasing mafic content, the calc-alkalic basalts are gradational into the Mg-tholeiitic basalts.

Carbonatization (calcite) is the most pervasive form of metasomatic replacement, and can form up to 50 percent by volume of the rocks; for example, near the east central boundary of Shaw Township

FELSIC CALC-ALKALIC METAVOLCANICS

Intermediate to felsic metavolcanics of calc-alkaline dacitic and rhyolitic composition are largely restricted to the area south of the Destor-Porcupine Fault, in particular to the northern and southern margins of the Shaw Dome. In addition, lesser quantities of intermediate to felsic metavolcanics form the uppermost volcanic succession in Tisdale and Douglas Townships. The felsic metavolcanics depicted in the northwest part of the area are compiled from the work of R.S. Middleton (1975).

In the southern half of Whitney Township and in that part of Deloro and Ogden Townships immediately south of the Destor-Porcupine Fault, the dacitic and rhyolitic metavolcanics appear to be almost entirely composed of tuff and lapilli-tuff; largely crystal tuffs of quartz and feldspar. The tuffs are light grey to light green, weather light grey, and are strongly foliated to schistose. The shistosity, imparted by the abundant development of sericite, lends a decided platyness or fissility to many of the rocks. Quartz fragments, 1 to 2 mm in diameter are common, and form 2 to 4 percent by volume of the rock. Only locally were fragments larger than lapilli size (> 2 mm) observed, and although the pronounced schistosity tends to obscure fragments it appears doubtful if much of the rock consisted of breccia. Rock fragments, where observed, are monolithic and have essentially the same composition as the matrix, namely quartz-sericite schist. The largest fragments observed, up to 15 cm in maximum dimension, outcrop in north-central Deloro Township. Pyrite is a common accessory mineral and imparts a rusty stain to some of the weathered surfaces. South of Porcupine Lake and in northern Deloro Township, minor interlayered lean sulphide iron formation is common, and large irregular patches of the tuffaceous quartz-sericite schist are stained orange-brown to purple.

In proximity to quartz porphyry intrusions, in particular at Mt. Logano in the northeast corner of Shaw Township, it is difficult to discern the contact between the porphyry and the surrounding tuffs. The contact is gradational in that the porphyry is strongly foliated at the margins and passes imperceptibly over a distance of 60 to 140 m into what appears to be the tuffaceous quartz-sericite schist. Much of this schist has for consistency been mapped as tuff, but could quite conceivably represent a sheared marginal phase of the porphyry.

This is dealt with in more detail in a later section concerning the porphyries.

In thin section, it is seen that quartz grains, generally in the size range 0.1 to 0.5 mm constitute 10 to 60 percent of the rock. The quartz is either: (1) set in a fine-grained (0.04 mm) mosaic of quartz and feldspar, throughout which very fine sericite flakes (rarely greater than 0.6 mm in length) are interwoven, or (2) engulfed in a dense matte of sericite, forming up to 40 percent of the rock. Minor small irregular blebs and elongate lenses of calcite are common as are narrow discontinuous bands of chlorite. Accessories include sphene, apatite, and opaque minerals.

The dacitic-rhyolitic metavolcanics depicted on the map (see Map 2455, back pocket) at the southern margin of the Shaw Dome, principally, in Langmuir and Eldorado Townships, are not well exposed. It is now suspected that the extent of these rocks, previously mapped by the author (Pyke 1970, 1975), has been over-emphasized. Most of the dacitic to rhyolitic volcanic rocks are probably largely within the stratigraphic interval containing the bulk of the iron formation. This cannot be substantiated by analyses at this time, but is based on a comparison of available hand specimens and thin sections from this part of the area with other calc-alkalic rocks within the Shaw Dome. Furthermore, the extremely low outcrop density, less than one percent, in this part of the area renders any contact somewhat arbitrary. A few good outcrops can be seen in central Eldorado Township and near the southeast boundary. Most are fine-grained crystal tuffs, dominantly massive, although layering, 2 to 40 mm thick, is locally evident.

In south Tisdale Township and the northwest corner of Deloro Township, a coarse pyroclastic breccia (Photo 23), termed the Krist fragmental (Ferguson *et al.* 1968), forms the uppermost volcanic succession within two synclinal structures. The breccia weathers light grey to white, and is light grey on the fresh surface. Breccia sized fragments are rarely up to 40 cm in maximum dimension and most are in the range of 1 to 3 cm. Nearly all the fragments are composed of feldspar-crystal tuff, very similar in composition to the matrix of the breccia, and not uncommonly, the two can be difficult to discern. Minor fragments other than crystal tuff include basalt, fuchsite, and iron formation. Fragment shape varies from angular to subrounded. On weathered surfaces, the matrix appears to be largely composed of feldspar crystals varying from 0.5 to 5 mm in size. Lesser quartz fragments are of a comparable to somewhat larger size.

In thin section, the breccia matrix is revealed to be composed of 40 to 75 percent by volume of anhedral to subhedral albite crystals, partly altered to sericite and carbonate. Anhedral quartz fragments form 3 to 8 percent by volume. The plagioclase and quartz fragments are set in a very fine grained mesostasis of feldspar and quartz. Minor (5 to 10 percent) chlorite and carbonate occurs as patchy segregations throughout the matrix. Rock fragments generally differ from the matrix only by having a differing fragment to matrix ratio and differing fragment size.

Layering is rarely observed in the breccia, yet at the same time, there is a suggestion that detailed inspection of the breccia may reveal a subtle, though thick layering in the order of 20 to 40 m. The monolithic character of the fragments, as well as the compositional and textural similarity of the matrix and fragments, warrants a detailed study of the clast size, distribution, and variations to aid in determining the genesis. Nevertheless, the general observations

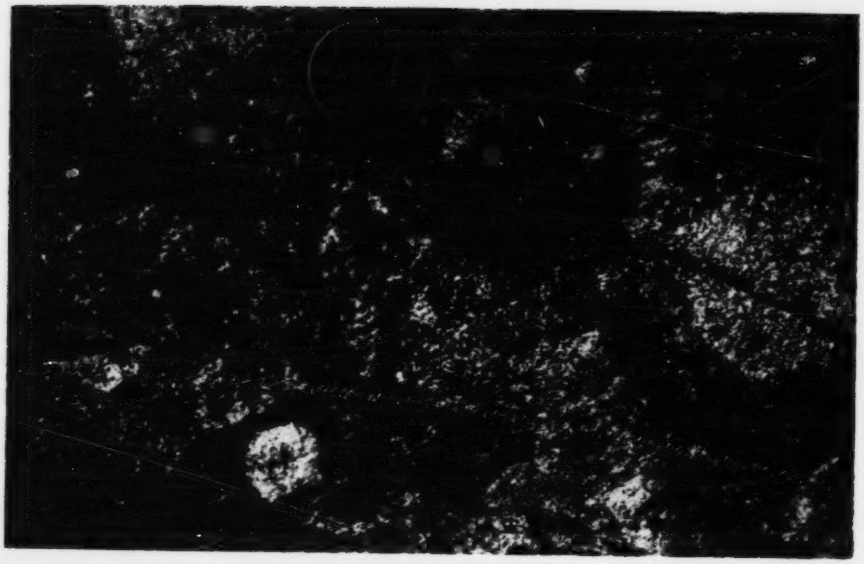

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Photo 23–Pyroclastic breccia (Krist fragmental). Outcrop on power line by highway 101, Tisdale Township.

made during the current mapping would suggest that the breccia formed as a glowing avalanche type of deposit. This is indicated by the general lack of obvious layering, monolithic character of the fragments, and the apparent heterogeneity of fragment size and distribution within any one outcrop.

CHEMISTRY OF THE CALC-ALKALIC METAVOLCANICS

The calc-alkalic rocks are best differentiated by means of the AFM diagram (Irvine and Baragar 1971) or the cation plot (Jensen 1976). For consistency with the other volcanic rock types in the area, the Jensen Cation plot is used to designate the calc-alkalic volcanic rocks as either basalt, andesite, rhyolite, or dacite.

Perhaps the most distinguishing chemical feature of the calc-alkaline suite is the higher aluminium and alkali contents as compared to the tholeiitic suite (Figure 8a); this largely reflects an increase in the volume percent plagioclase. This distinction is particularly useful in reference to the calc-alkalic basalts and andesites because felsic tholeiitic differentiates are rare as compared to those of calc-alkalic affinity. Nearly all the calc-alkalic volcanic rocks contain greater than 15 percent Al_2O_3, and most more than 16 percent (Figure 8b).

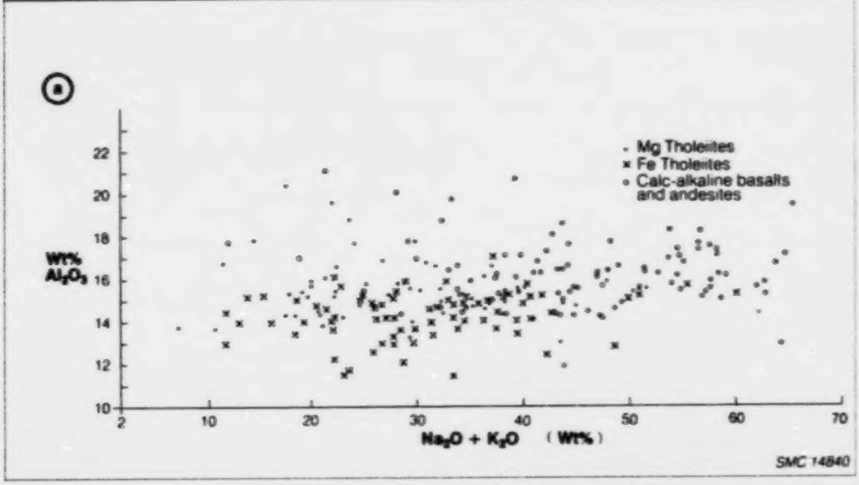

Figure 8a–Al_2O_3 vs Na_2O + K_2O diagram for tholeiitic basalts and calc-alkaline basalts and andesites.

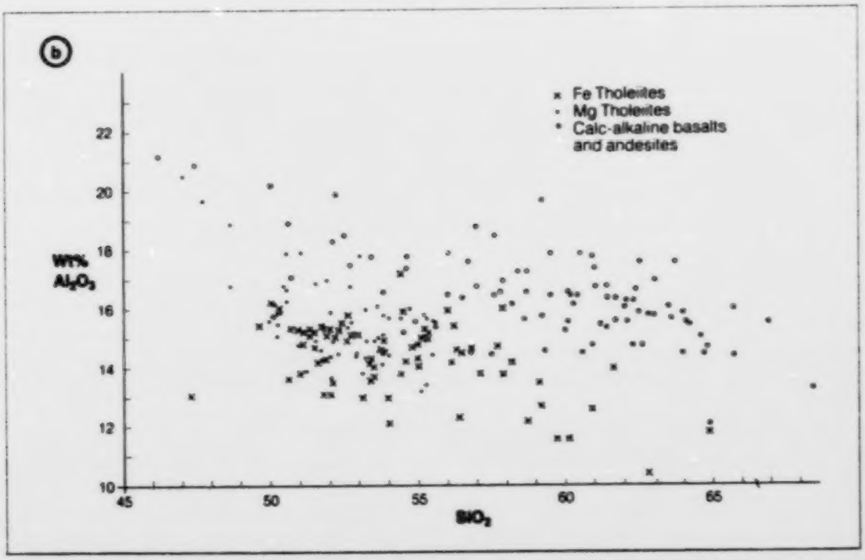

Figure 8b–Al_2O_3 vs SiO_2 diagram showing differences in composition between tholeiitic basalts and calc-alkaline basalts and andesites.

Most tholeiites contain less than 15 percent Al_2O_3; indeed, for any given aluminium content, most tholeiites contain less silica and alkalies than calc-alkalic basalts and andesites.

METASEDIMENTS

Iron Formation

Iron formation forms a conspicuous and persistent stratigraphic unit in the area, and is virtually confined to the upper formation of the Deloro Group. Oxide and sulphide facies are prominent; carbonate facies iron formation was rarely observed, and only locally forms minor intercalations with dominantly magnetite- and pyrite-bearing zones.

Outcrops of iron formation are in general poor; some of the best exposures are in southwest Whitney Township and north-central Shaw Township. The location of the iron formations in much of Langmuir, Eldorado, and Adams Townships is to a large degree supplemented by geophysical and diamond-drill hole information.

Oxide facies iron formation typically consists of alternating layers of magnetite and chert. The magnetite layers are 1 mm to 80 mm thick, average approximately 10 to 20 mm in thickness, and consist of fine-grained granular magnetite and minor (generally 10 percent) chert. Chert layers are light grey to white weathering and fresh, vary from a few millimetres to 30 cm or more in thickness, commonly average approximately 1 to 3 cm, and are almost invariably present in an amount in excess of magnetite-rich layers;chert-magnetite ratios are rarely less than approximately 3 to 2. The chert is recrystallized to a fine-grained granular mosaic. On some weathered surfaces, a fine lamination, 0.05 to 1.0 mm thick, is discernable; this is suggestive of a primary layering. Rare grains of pyrite, pyrrhotite, and magnetite are common in the chert layers.

Minor black argillaceous sedimentary rocks form layers up to 3 m thick. Narrow, soft, dark green chloritic layers are locally present.

Sulphide facies iron formations are dominantly composed of white to light grey or pale red ferruginous chert. Layers of sulphide, graphite, argillite, and rarely minor magnetite form a variable part of many of the iron formation zones. Locally, very massive appearing finely granular chert constitutes virtually all the exposed iron formation unit, as for example in northwest-central Shaw Township, 1.5 km southwest of Mt. Logano. Pyrite, generally associated with minor pyrrhotite, is the dominant sulphide and characteristically occurs in narrow 2 cm thick layers, fine disseminations, or stringers in chert. Other sulphide minerals include minor chalcopyrite, pentlandite, and rare sphalerite, and galena. In general, sulphide minerals constitute less than 10 to 15 percent of an iron formation; less commonly, zones contain 30 to 85 percent sulphide minerals and are up to 5 m thick.

At two localities, immediately northwest of the Langmuir deposit shaft, and near the southwest corner of Goose Lake, the pyrite was observed to occur as spherulitic-like concretions (up to 1 cm diameter) displaying both a concentric and radial structure within a matrix of concretion fragments and finely banded pyrite. Graphite, forming layers from 1 cm to 2 m thick, is particularly abundant in south Whitney Township.

Many of the iron formation units display complex folding and many of the chert layers are disrupted and broken, the dilatant zones being filled by magnetite or pyrite. The author interprets much of this complex folding as soft-sediment deformation.

Much of the iron formation does not appear to form a continuous layer, especially in the southern part of the Shaw Dome. Rather, for the most part, it appears to form a series of disconnected, isolated lenses, perhaps in part forming an *en echelon* type arrangement.

Maximum thickness of either facies of iron formation is approximately 46 m, but most is less than 30 m, and many are in the order of 6 to 12 m.

Some of the more obvious generalizations regarding the distribution of the iron formation in the map-area are:

(1) Virtually all the iron formation is within the upper formation of the Deloro Group.

(2) Sulphide facies iron formation dominates in the southern part of the Shaw Dome in Adams, Eldorado, Langmuir, and Carman Townships. The ratio is nearer 1:1 in the north part of the Shaw Dome.

(3) When both oxide and sulphide facies iron formation are present, the sulphide facies occupies the higher stratigraphic position.

PORCUPINE GROUP

The clastic metasediments in the Timmins area have recently been classified as the Porcupine Group by J. Lorsong (1975), who has subdivided the group into four formations. From the oldest to the youngest formation, these are the Whitney, Beatty, Dome, and Three Nations Lake Formations. A breakdown of the formations as proposed by Lorsong (1975) is shown in Figure 9. On the stratigraphic map, (*see* Figure 19) only two subdivisions of the sedimentary rocks are shown because the Beatty, Dome, and Three Nations Formations have been combined. Much of the following description of the Porcupine Group is summarized from Lorsong (1975).

Whitney Formation

The Whitney Formation, the oldest metasedimentary sequence in the area, is best exposed in the northeast corner of the area in Cody Township, although even here the exposure is relatively poor. This is perhaps the most lithologically diverse formation and consists largely of siltstones and minor feldspathic wackes in the basal part, and intermediate to mafic tuffs interlayered with minor siltstone in the upper part. Total thickness may be as great as 1000 m, but it is difficult to estimate this because of minor structural complications (see Le-

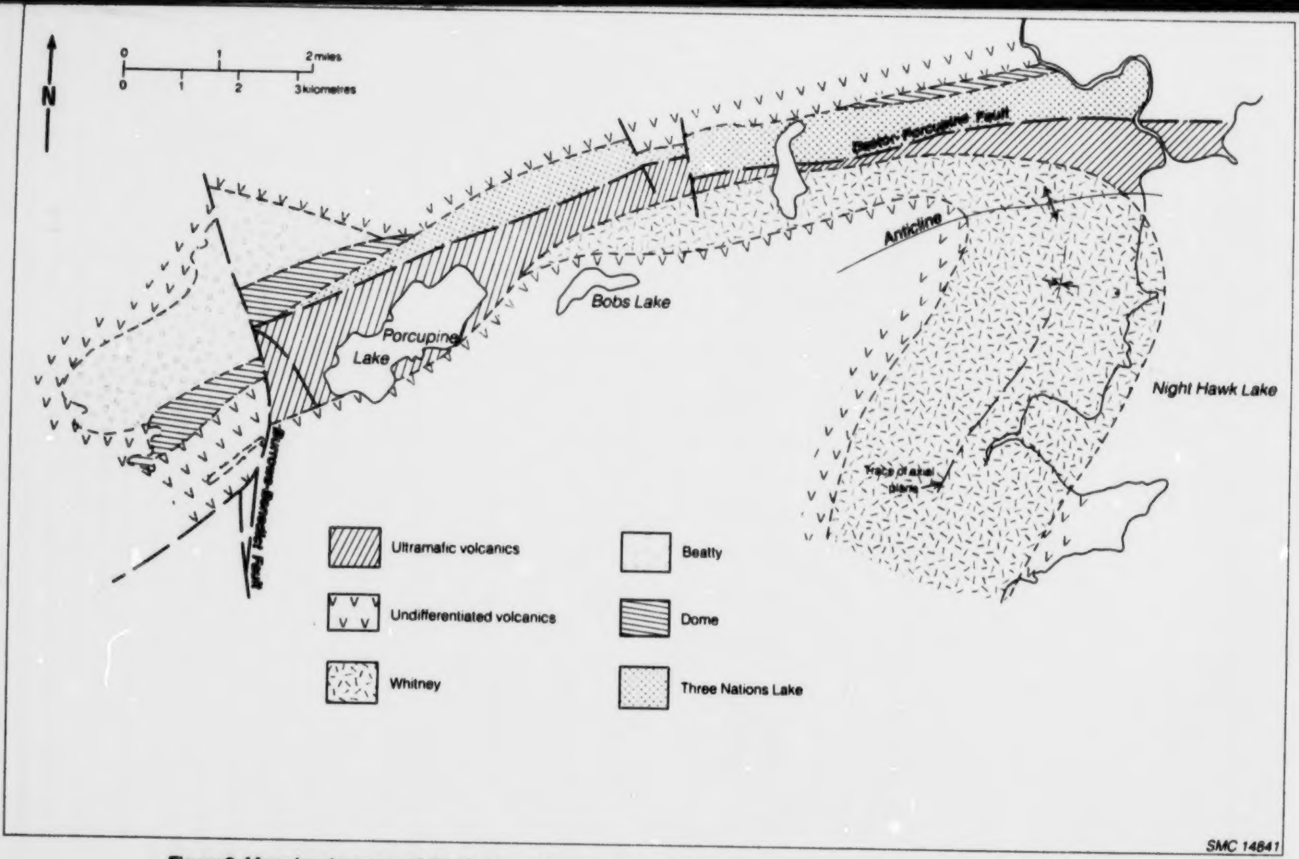
N
0 1 2 miles
0 1 2 3 kilometres
Destor-Porcupine Fault
Anticline
Bobs Lake
Porcupine Lake
Night Hawk Lake
Trace of axial plane
Burrows-Benedict Fault
Ultramafic volcanics
Undifferentiated volcanics
Whitney
Beatty
Dome
Three Nations Lake
SMC 14841

Figure 9—Map showing general distribution of formations in the Porcupine Group metasediments (after Lorsong 1975).

ahy 1971). Only one analysis is available from this area in Cody Township, and that is of a basaltic tuff (Sample P-530-75, Table III, see back pocket) interlayered with the siltstones. The author would also correlate the sedimentary rocks in Thorneloe and Bristol Townships with the Whitney Formation; from the limited exposure these rocks appear to be interlayered with volcanic rocks of the upper part of the Deloro Group and the lower part of the Tisdale Group. Similarly, the metasediments in western Tisdale and Mountjoy Townships are also tentatively correlated with the Whitney Formation. Even if all the above metasediments are not directly correlative, one common feature these rocks have is being largely stratigraphically below the remaining metasediments in the area. Furthermore, the Whitney Formation appears to be largely time equivalent to the Tisdale Group, particularly in the vicinity of Thorneloe Township.

Beatty and Dome Formations

The Beatty Formation is a turbidite sequence of wackes and siltstones (Photo 24) which overlies the Tisdale Group with apparent conformity (best illustrated on Map 2075 by Ferguson *et al.* 1968, in concession IV, lots 1 and 11). The maximum thickness of the Beatty Formation is approximately 1050 m. An angular unconformity separates the Beatty Formation from the overlying Dome Formation; this unconformity is best exposed in the outcrops north of South Porcupine near the west-central boundary of Tisdale Township (*see* Map 2075, Ferguson *et al.* 1968). Here, a polymictic conglomerate containing subrounded clasts, ranging in size from pebbles to boulders, truncates the underlying Beatty Formation at an angle of approximately 30 degrees. According to Lorsong (1975), this angular unconformity appears to be only of local significance, consisting of a complex aggregate of channel fills. Nevertheless, there must have been significant tectonic tilting prior to the deposition of the Dome Formation; nowhere does bedding, south of the unconformity, in either the Dome or overlying Three Nations Lake Formations, approach conformity with the Beatty Formation (best illustrated on maps of Hurst 1939 and Ferguson *et al.* 1968). Mafic metavolcanics are the dominant clasts in the conglomerate, others include metasediments, felsic and ultramafic metavolcanics, gabbro, and quartz-feldspar porphyry. The Dome Formation is largely a turbidite sequence, and has a maximum thickness of 400 m.

In the turbidites of the Beatty and Dome Formations, bedding contacts are very planar, and are interrupted infrequently by flute casts, scour marks, flame structures, and rarely slump structures. The wackes are fine to medium grained, light grey brown weathering, commonly graded, and consist dominantly of lithic wackes (Figure 10a and Tables 2 and 3), and rare arkosic wacke. The wackes average approximately 11 percent quartz, 20 percent feldspar, 44 percent lithic fragments, and 25 percent matrix. The quartz is angular, varies in size from 1.0 mm to 0.02 mm and averages about 0.1 to 0.2 mm. The feldspar is of a comparable size to the quartz, and is generally twinned. Rock fragments are mainly metavolcanics (primarily mafic?); there are also a few granitic fragments, some containing potassic feldspar. The matrix is often hard

OGS 10 395

Photo 24–Well-layered turbidites of the Beatty Formation. Near east-central margin of Tisdale Township.

to distinguish from fragments and is mainly extremely fine grained quartz-feldspar and sericite. Minor carbonate, chlorite, and opaque minerals are common.

In the siltstones, where exposures permit, a very fine planar lamination is commonly observed; other structures include minor convolute bedding and rare crossbedding.

In thin section, the siltstones are revealed to consist of 5 to 10 percent scattered quartz grains 0.02 mm in size, set in an extremely fine (< 0.01 mm) matrix of largely quartz, feldspar, and sericite.

The beds are readily interpreted as part of the Bouma sequence. Division A includes most wackes and some lutites; division B includes most lutites and some wackes, and division C, a few lutites. In only one bed was a complete Bouma sequence observed (Lorsong 1975) including divisions A, B, C and D (*see* Photo 25).

Lorsong (1975) noted that a feature common to many of the turbidites was the occurrence of "thin" and "thick" bedded sequences. Thin bedded sequences display regular alternations of wackes (10 to 15 cm thick) and siltstones (5 to 10 cm thick). In thick-bedded sequences, the wacke beds are typically in the order of 100 cm thick and are separated by thin (2 to 3 cm thick) lutite beds. On lichen-free exposures many of the thick beds of wackes are seen to be composite

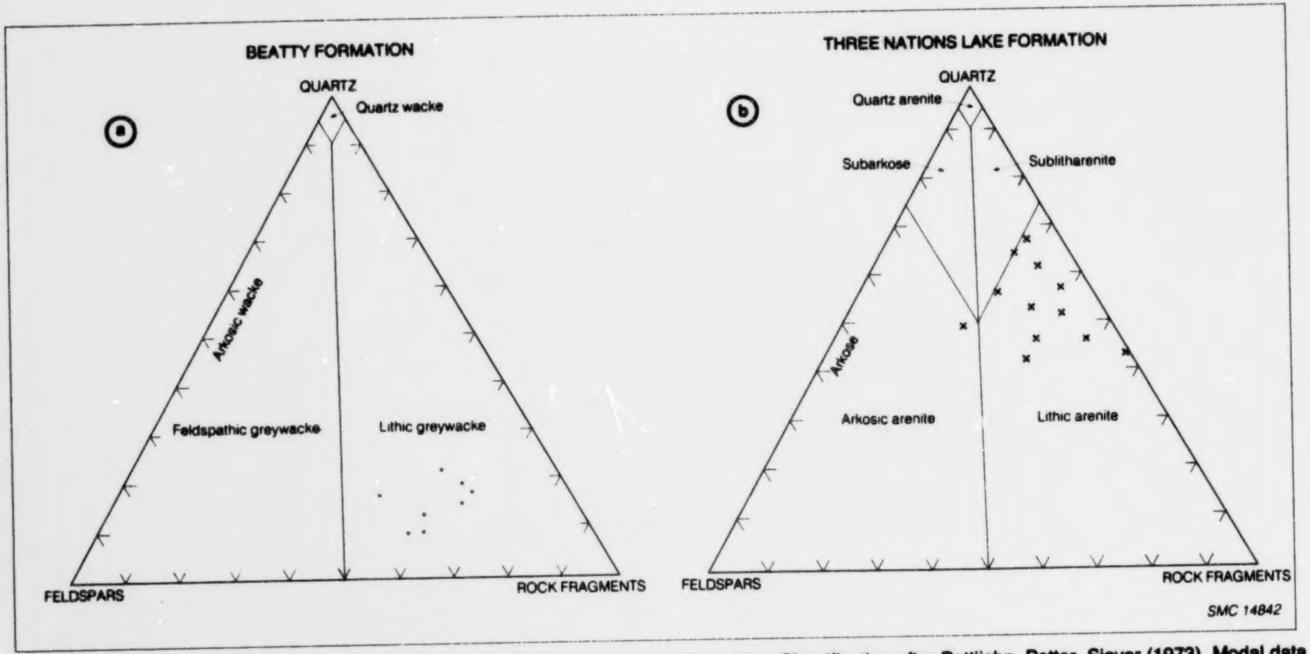

Figure 10a–Feldspar-quartz-rock fragment diagram for sandstones of the Beatty Formation. Classification after Pettijohn, Potter, Siever (1973). Modal data from Lorsong (1975).

Figure 10b–Feldspar-quartz-rock fragment diagram for sandstones of the Three Nations Lake Formation. Classification after Pettijohn, Potter, Siever (1973). Modal data from Lorsong (1975).

TABLE 2 | **MODAL ANALYSES OF SANDSTONE FROM THE BEATTY FORMATION.**

Specimen Number	Qtz	Fsp	Lf	Matr	Carb	Py	Hvy	Q	F	L
Beatty Sandstones East										
L50-74	12	7	42	39	TR	TR		19	12	69
L51-74	8	12	35	45	NIL	NIL	NIL	15	22	63
L177-74	7	15	25	53	NIL	NIL	NIL	15	32	53
Beatty Sandstones West										
L31-74	14	15	53	17	1	TR	NIL	17	18	65
L65-74	14	14	43	29	NIL	NIL	NIL	19	19	62
L69-74	11	15	46	28	TR	NIL	NIL	15	21	64
L231-74	8	25	49	16	TR	1	1	9	31	60
L231-74	11	24	46	18	NIL	TR	1	13	29	58
L233-74	13	26	35	17	9	NIL	NIL	17	35	48
L234-74	6	24	41	29	TR	NIL	NIL	9	34	57
L240-74B	15	16	41	21	7	NIL	NIL	21	22	57

Abbreviations

Qtz	Quartz
Fsp	Feldspar
Lf	Labile Fragments
Matr	Matrix Minerals
Carb	Carbonate Minerals
Py	Pyrite
Hvy	Heavy Minerals
Q	Quartz
F	Feldspar
L	Labile Minerals
Tr	Trace

because they consist of a number of beds, each 10 to 15 cm thick. Thin and thick bedded sequences attain thicknesses of 250 m respectively; typical thicknesses are approximately 15 m.

Three Nations Lake Formation

The Three Nations Lake Formation is composed of interbedded sandstone and conglomerate. The sandstone is largely a lithic arenite (Figure 10b, and Table 2) averaging about 45 percent quartz fragments, 10 percent feldspar fragments, 30 percent lithic fragments and 15 percent matrix. The quartz fragments are angular, range in size from 0.1 to 5 mm and average approximately 0.5 to 1.0 mm. Approximately 10 percent of the quartz fragments are polycrystalline. The feldspar fragments average 0.25 to 0.5 mm, are smaller than the quartz grains, are generally untwinned, and display various degrees of altera-

TABLE 3 MODAL ANALYSES OF SANDSTONE FROM THE THREE NATIONS FORMATIONS.

Specimen Number	Qtz	Fsp	Lf	Matr	Carb	Py	Hvy	Q	F	L
Three Nations Lake Sandstones East										
L170-74	63	6	24	7	TR	NIL	NIL	68	6	26
L218-74	57	7	23	12	NIL	NIL	NIL	65	8	27
Three Nations Lake Sandstones West										
L90-74	50	16	23	6	5	NIL	NIL	56	18	26
L91-74A	42	11	27	11	9	TR	NIL	53	13	34
L92-74A	55	9	21	8	8	NIL	NIL	64	11	25
L92-74B	50	5	19	10	15	1	NIL	67	7	26
L191-74B	46	6	23	11	14	NIL	NIL	61	8	31
L198-74C	48	8	37	5	2	NIL	NIL	51	9	40
L198-74D	39	14	33	11	3	NIL	NIL	46	16	38
L199-74	51	5	34	5	5	NIL	NIL	57	6	37
L202-74	40	6	41	8	5	NIL	NIL	46	7	47
L203-74A	36	TR	47	14	3	NIL	NIL	43	0	57
L203-74B	52	1	35	6	6	NIL	NIL	59	1	40
L238-74A	38	18	35	9	NIL	NIL	NIL	421	20	38
L239-74	44	25	21	10	TR	NIL	NIL	49	26	23
Three Nations Lake Feldspathic Sandstones										
L204-74	18	35	33	13	NIL	1	NIL	21	41	38
Miscellaneous										
L194-74	13	NIL	NIL	17	70	NIL	NIL			
L196-74	46	NIL	NIL	23	31	TR	NIL			
L214-74	16	NIL	NIL	33	51	TR	NIL			

Abbreviations

Qtz	Quartz
Fsp	Feldspar
Lf	Labile Fragments
Matr	Matrix Minerals
Carb	Carbonate Minerals
Py	Pyrite
Hvy	Heavy Minerals
Q	Quartz
F	Feldspar
L	Labile
Tr	Trace

tion to sericite. In some instances it is difficult to distinguish feldspar grains from matrix. The matrix is largely a fine (0.02 mm) aggregate of quartz and lesser (?) feldspar with minor sericite and patches of chlorite and carbonate. Opaque minerals are less than one percent.

A noteable feature of the Three Nations Lake Formation is the abundance of large scale crossbedding (30 to 100 cm amplitude); more than half the beds

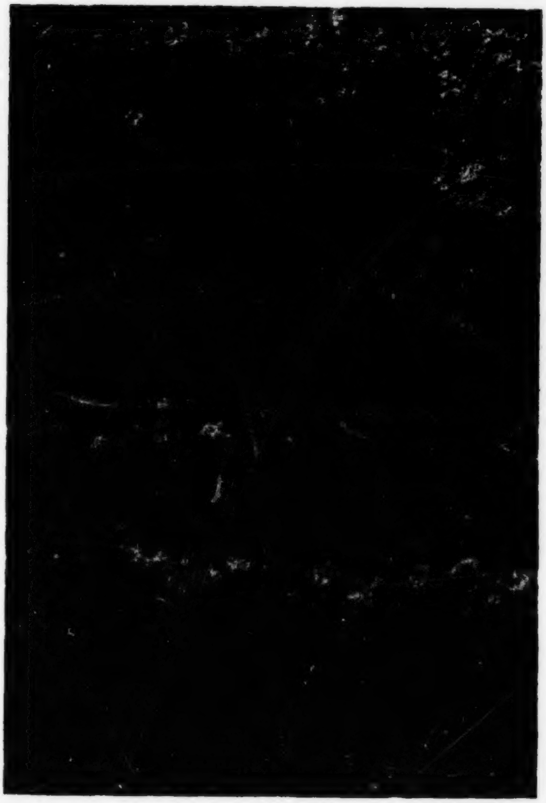

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Photo 25–Bouma Sequence in Beatty Formation, Tisdale Township.

possess this feature (Photo 26). Both ripple drift and festoon crossbedding are present, the latter being particularly well developed in two bands near Three Nations Lake. Bedding is typically lenticular; however, in parts of the formation persistent fine layering is prominent (Photo 27).

Three pebble conglomeratic horizons (Photo 28) spaced roughly 150 m apart, are recognized in the Three Nation Lake Formation (Lorsong 1975). Conglomeratic-sized fragments range from 0.5 to 15 cm, average approximately 2 cm, are rounded to subrounded, and form an intact framework. Crossbedding is common. Major clast lithologies are buff-coloured siltstones, felsic volcanic rocks, and fuchsitic ultramafic clasts; lesser trondhjemite, chert, and

OGS 10 397

Photo 26–Crossbedding in lithic arenite, Three Nations Lake Formation, north-central Whitney Township in outcrop area by Three Nations Lake.

vein quartz clasts are also present. The ultramafic clasts display soft-sediment features in that they have sharp curvilinear boundaries (*see* Photo 29) with the surrounding pebbles that result from the squeezing of the ultramafic clast while it was still in a semi-consolidated state.

The contact between the Dome and Three Nations Lake Formations is not exposed, but bedding on either side of the contact is conformable. The contact is nearly exposed in lot 12, concession IV, Whitney Township, where the two formations are separated by a shallow depression about 3 m wide. Here, a largely oligomictic conglomerate, consisting almost entirely of ultramafic clasts (some spinifex - textured) and a few quartz and porphyry fragments forms the top of the exposed Dome Formation and the base of Three Nations Lake Formation. The above-mentioned depression lies immediately south of the conglomerate. This sedimentary contact is perhaps the most significant in the Timmins area because it represents a major change in sedimentation from turbidite to fluviatile.

Lorsong (1975) interpreted the Three Nations Lake Formation to be a proximal submarine alluvial fan sequence. A quartz-rich source area, largely a granitic terrain, is implied from the abundance and coarse grain size of the quartz. Conceivably, the quartz may have been concentrated in the source area from residual weathering rather than extensive reworking.

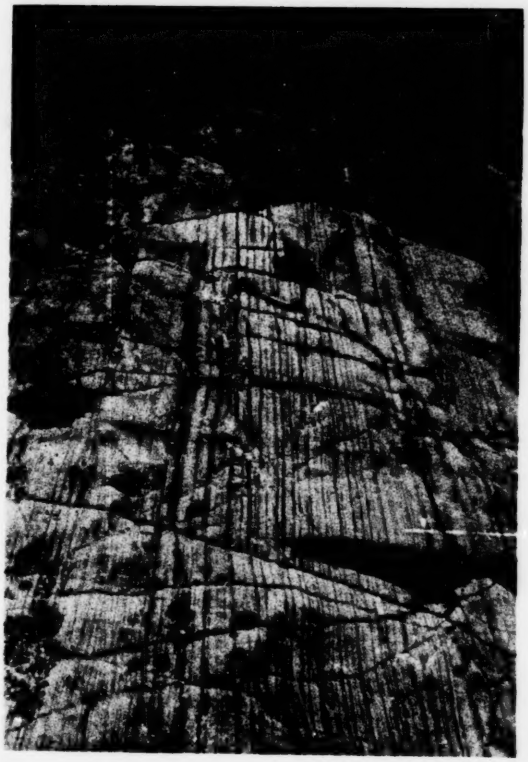

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Photo 27–Fine- to medium-bedded lithic arenite in Three Nations Lake Formation. Same outcrop area as Photo 26.

METAMORPHOSED ULTRAMAFIC AND MAFIC INTRUSIVE ROCKS

Metamorphosed ultramafic and mafic intrusive rocks are almost wholly confined to that part of the area within the Shaw Dome. The ultramafic intrusive rocks are composed almost entirely of peridotites, which comprise dunites, lherzolites, harzburgites, and wehrlites, as defined by the classification scheme (Figure 11) given by Streckeisen (1973). The distinction between the dunitic and the lherzolitic field, including the harzburgites and wehrlites, is not practical because many of the compositions lie near the dunite boundary (90 percent olivine), and it is almost impossible in many cases to accurately determine the

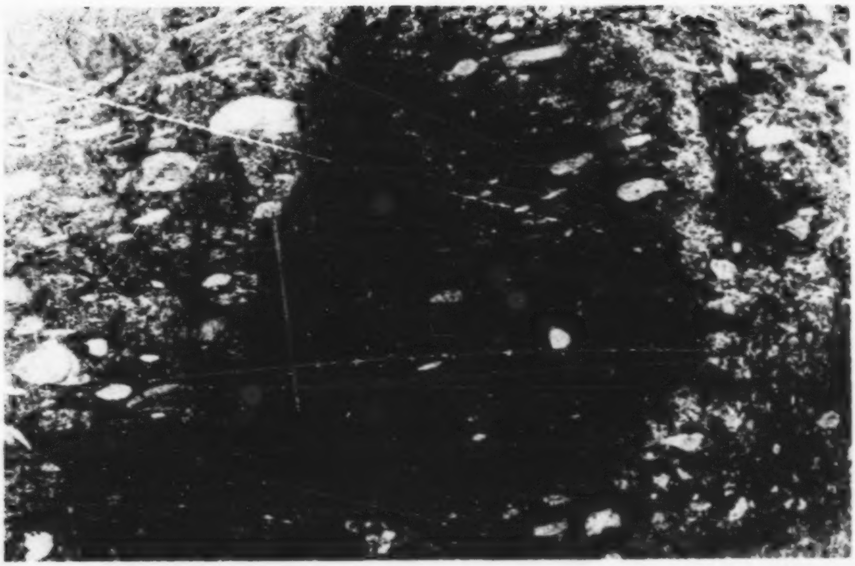

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Photo 28–Conglomerate of the Three Nations Lake Formation.

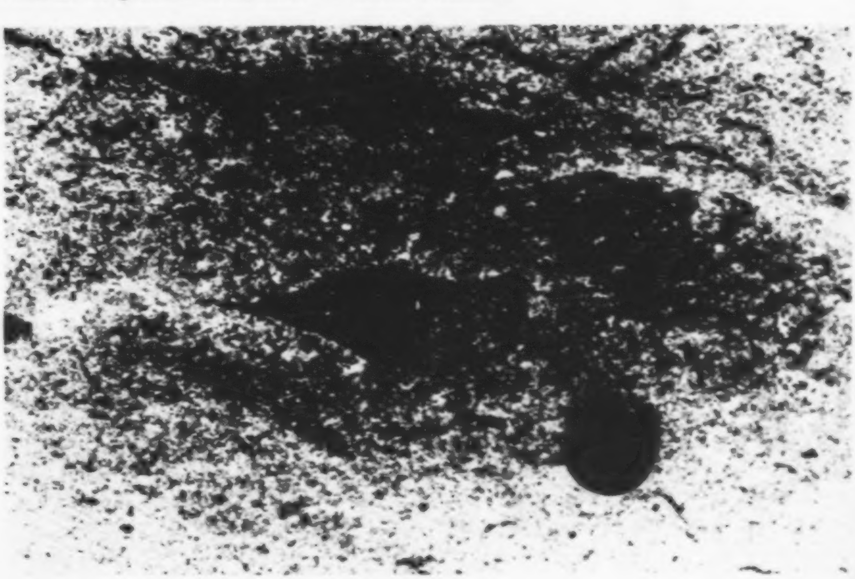

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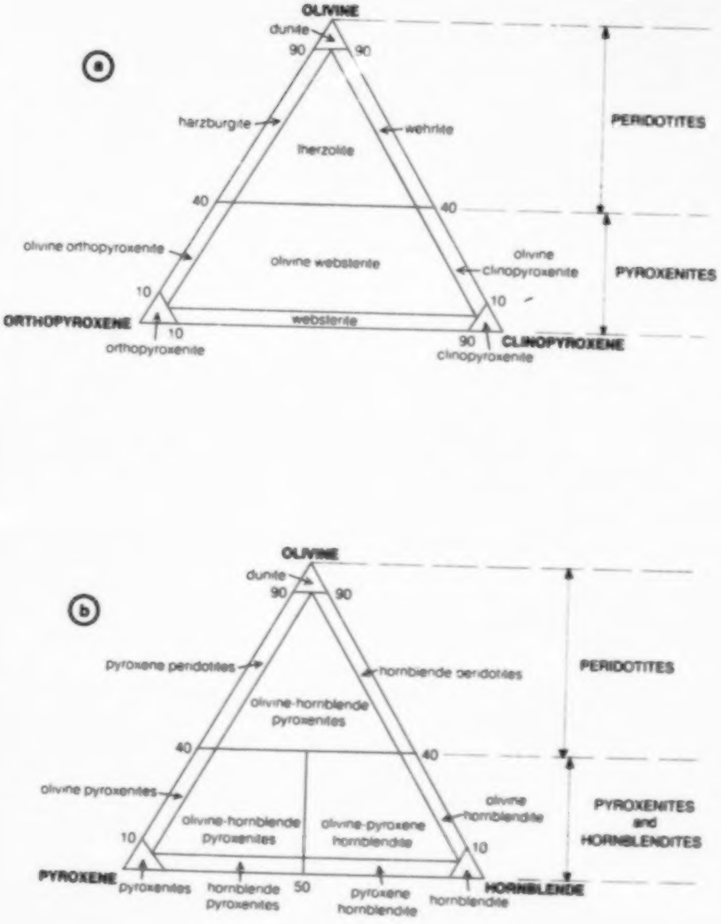
Photo 29–Curvilinear fuchsite fragment in conglomerate of Three Nations Lake Formation.


a
OLIVINE
dunite
90
90
harzburgite
lherzolite
wehrlite
PERIDOTITES
40
40
olivine orthopyroxenite
olivine websterite
olivine
clinopyroxenite
PYROXENITES
10
10
websterite
ORTHOPYROXENE
10
90
orthopyroxenite
clinopyroxenite
CLINOPYROXENE
b
OLIVINE
dunite
90
90
pyroxene peridotites
hornblende peridotites
olivine-hornblende
pyroxenites
PERIDOTITES
40
40
olivine pyroxenites
olivine-hornblende
pyroxenites
olivine-pyroxene
hornblendite
olivine
hornblendite
PYROXENITES
and
HORNBLENDITES
10
10
PYROXENE
pyroxenites
hornblende
pyroxenites
50
pyroxene
hornblendite
hornblendite
HORNBLENDE

SMC 14843

Figure 11–Classification of ultramafic rocks after Streckeisen (1976).

modal mineralogy because of the extensive alteration. From the surface expression, many of the ultramafic intrusive rocks appear to be conformable sill-like bodies in that they tend to follow the trend of the enclosing rocks. Nowhere were the contacts observed by the field party. Intrusive contacts, however, have been observed underground at the Langmuir Mine along the east-central boundary of the area (A. Green, personal communication, 1977). In addition, minor peridotitic dikes, presumably representing apophyses of the sills, intrude the nearby volcanic rocks near the periphery of the Shaw Dome.

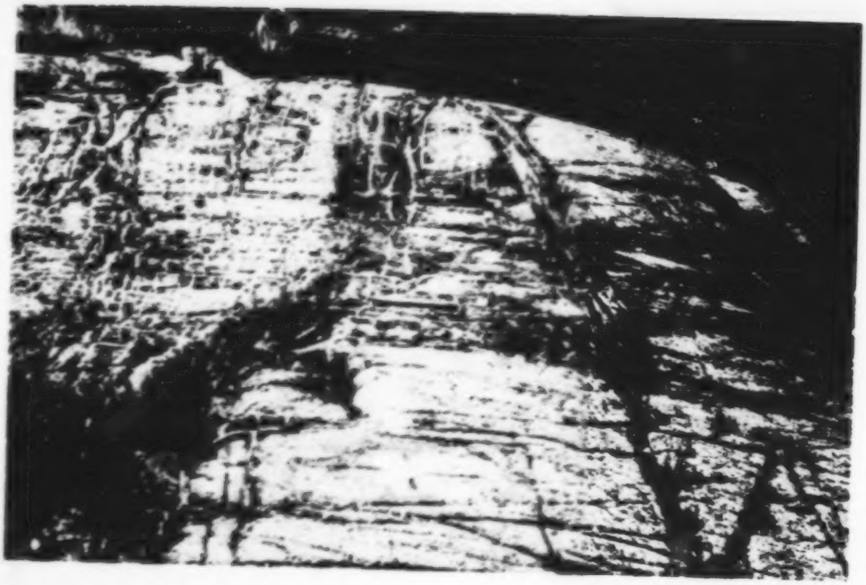
Locally, the upper part of the peridotitic sills contains minor ultramafic and gabbroic differentiates. These are chemically indistinguishable from the ultramafic flows and related basaltic komatiites and Mg-tholeiitic basalt. This suggests not only a common parentage for the intrusive-extrusive assemblages, but that some of the ultramafic intrusions may have provided a magma reservoir from which overlying flows were derived.

Meta-Peridotitic (Dunite-Lherzolite) Intrusions

The peridotitic, or ultramafic intrusive rocks of the Timmins area are composed largely of dunite, and were emplaced wholly within the Deloro Group confined to the area of the Shaw Dome. Outcrops weather light to medium grey or orange-brown; fresh surfaces are a typically bluish black and rarely light green. Where the rocks have undergone extensive replacement by carbonate and talc, fresh surfaces are light to medium grey or brown. Most outcrops display a somewhat rectangular joint pattern (Photo 30); spacing of the joints commonly varying from 2 to 30 cm. The best-developed joint set is generally subparallel to the trend of the intrusive body. Discontinuous curvilinear fractures are also common, and characteristically have numerous small closely-spaced fractures perpendicular to the main fracture plane. These impart a zipper-type appearance (Photo 31), hence the term zipper-fractures. Neither the rectangular joint patterns nor the zipper fractures occur in the extrusive ultramafic rocks, and conversely, polysuturing, diagnostic of ultramafic flows does not form in the ultramafic intrusions.

The dunitic composition of many outcrops is readily seen on the weathered surface. Densely packed grains of olivine are slightly recessed relatively to the perimeter of the grains which are commonly outlined by narrow concentrations of magnetite; the overall effect is one of a honeycomb-type of texture.

Minor asbestos (chrysotile) seams and veinlets are common in many of the outcrops, but only in two localities, central and east-central Deloro Township have the concentrations proven to be of commercial importance. At the former Bowman Mine property (currently held by Nakhodas Mining Company Limited) in central Deloro Township, excellent exposures of subparallel to anastomising veinlets of asbestos (Photo 32) are exposed in outcrops immediately south of the old mine workings. Here asbestos veinlets varying from 0.05 to 1 cm in thickness are concentrated mainly in two zones traceable over a strike length of 40 m, and have maximum widths of 10 and 3 m respectively. In these zones, the asbestos veinlets form up to 15 percent by volume of the rock. Commonly, magnetite is intimately intergrown with the asbestos. The magnetite has a

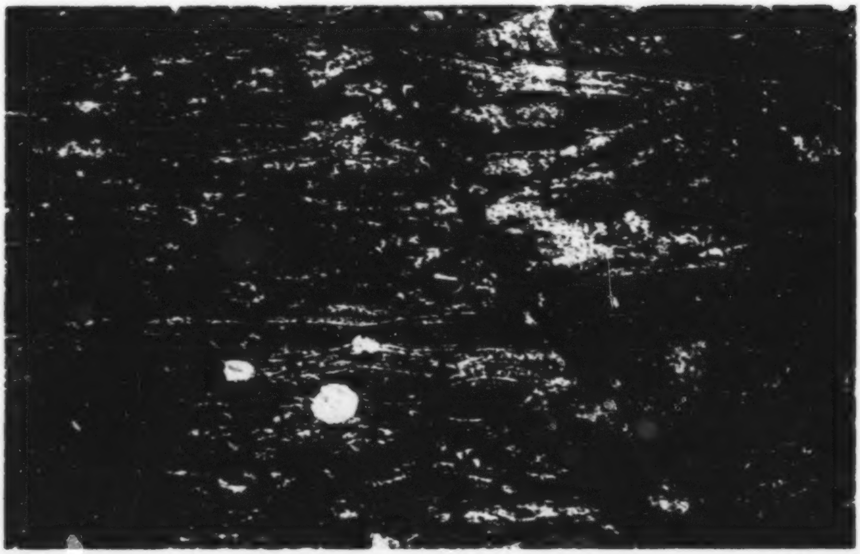


OGS 10 401

Photo 30–Serpentinized dunite with characteristic regular joint or fracture pattern. Central Deloro Township near former Bowman Mine.

OGS 10 402

Photo 31–Zipper fractures in serpentinized dunite. Near former Bowman Mine, Central Deloro Township.



OGS 10 403

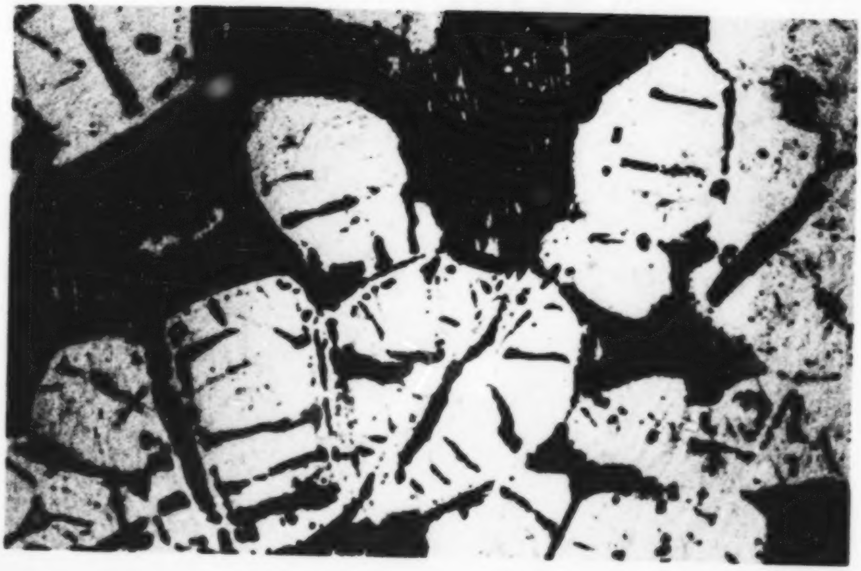
Photo 32–Anastomizing asbestos veinlets in serpentinized dunite. 150 m south of main pit at former Bowman Mine, Deloro Township.

pseudo-asbestiform habit, or alternatively, the magnetite may form massive veinlets alternating with seams of asbestos in the dunitic host rock.

Carbonate alteration is a common feature of many of the ultramafic rocks. The alteration varies from incipient replacement along grain boundaries to a virtually complete reconstitution of the rock composed of magnesite, talc, and quartz. Magnesite may form up to 70 percent by volume of the rocks, as in southern Deloro Township (Griffis 1972), but more commonly does not exceed 30 to 40 percent; the remainder consists of 5 to 25 percent talc, 3 to 20 percent quartz, 5 to 15 percent serpentine, and minor magnetite. Three main outcrop areas, located in south-central Whitney Township, the southern boundary of Deloro Township, and in west-central Eldorado Township respectively, show extensive alteration to magnesite-talc. These occurrences are discussed in detail in the section on "Economic Geology".

Veins and seams of talc are not common, and when present are generally associated with abundant carbonate. The most prominent talc veins noted are in east-central Eldorado Township; here, irregular veins of talc up to 75 cm thick transect an outcrop of dunite largely altered to carbonate and talc.

In thin section, the dunitic composition of many of the ultramafic sills is evident, because they consist mainly of serpentine pseudomorphous after olivine.



OGS 10 404

Photo 33–Photomicrograph of lherzolite. Serpentine pseudomorph after olivine; clinopyroxene altered to chlorite and magnetite.

Locally, minor talc and talc-carbonate pseudomorphically replace the olivine; however, extensive talc-carbonate alteration generally destroys the primary texture. No relict olivine was observed in any of the sections examined. Magnetite forms 1 to 10 percent by volume of the dunites, and is commonly concentrated at the margins of former olivine grains, and to a lesser extent along fractures in the grains. Magnetite may also be disseminated as fine dust-like particles throughout the rock; this is especially common in some of the ultramafic sills in Langmuir Township. In some instances, serpentinization has completely destroyed the primary texture, and the rocks consist of a non- descript fine-grained (less than 0.01 mm) matte of antigorite.

Toward the upper part of some of the sills, minor pyroxene is distinguishable in a few thin sections (Photo 33), and is altered to what appears to be largely chlorite and minor fine-grained dusty magnetite. Pyroxene could not be positively identified to have formed more than 10 to 12 percent by volume of any of the peridotitic bodies, and it is therefore concluded that only limited lherzolite developed, and that which did, was nearly dunitic in composition.

Texturally, the dunites consist of densely packed olivine grains. Much of the olivine tends toward an equant habit, although tabular crystals are not uncommon. When tabular, the length to width ratio was never observed to exceed

4 to 1 and is rarely greater than 3 to 1. Grain size varies from 1 to 5 mm, and most average 3 to 4 mm; tabular phenocrysts range from 4 to 15 mm in length, averaging about 8 mm. A combination of both the habit (tending to equant grains) and the coarse grain size, generally serves to distinguish dunitic intrusions from the cumulate parts of flows with which they could be confused. In contrast, the cumulate parts of flows rarely exceed 2 mm in grain size, and commonly contain a few elongate crystals of olivine with length to width ratios of 8 or 10 to 1. In addition, the flows have a more heterogeneous appearing texture as regards grain size, shape, and distribution. These textural differences are often sufficient to differentiate between the two types of ultramafics, and can be especially helpful in the examination of drill core where volcanic structures such as polysuturing, flow tops, etc., may not be as evident as on the weathered outcrop.

Differentiates of the Meta-Peridotitic Intrusions

Two main types of differentiates are associated with the dunitic intrusions: (1) ultramafic, consisting of what is termed pyroxene-hornblende peridotite, and (2) gabbroic, consisting of gabbro and quartz gabbro.

The contacts of these differentiates with the dunite-lherzolite bodies is only exposed in central Deloro Township where they form a narrow zone along the upper contact of the sill. Ultramafic differentiates were observed at only two other localities in the area. One is in the northeast quadrant of Shaw Township and the other is in west-central Langmuir Township.

In Deloro Township, the contact between dunite-iherzolite and the overlying hornblende-pyroxene peridotite is rapidly gradational. The pyroxene-hornblende peridotite weathers orange brown, not unlike the dunite, and has a maximum thickness of about 6 m. Microscopically, crystals of hornblende and pyroxene poikilitically enclose grains of serpentine pseudomorphous after olivine. The pyroxene has largely been altered to serpentine, chlorite, and tremolite; the hornblende has in part been altered to tremolite. Modal mineralogy is difficult to estimate, but is in the order of 40 percent olivine, 40 percent hornblende, 20 percent pyroxene.

A narrow zone of pyroxene hornblendite, up to 2 m thick, overlies the pyroxene hornblende peridotite. The contact is sharp, yet irregular; there are shallow embayments of one rock type in the other.

Hornblende gabbro and quartz hornblende gabbro form narrow, as much as 8 m thick, discontinuous zones along the top of the peridotitic sill in central Deloro Township. The contact with the underlying hornblendite is irregular. The gabbros are typically coarse grained, even locally pegmatoidal in texture (Photo 34); especially the quartz-bearing varieties where plagioclase grains are up to 2 cm in length. The ratio of plagioclase to mafic minerals varies from about 1:3 in the hornblende gabbros to about 2:1 in the quartz gabbros (Muir 1975).

Elsewhere throughout the area, minor isolated outcrops of fine- to medium-grained, medium grey-green gabbro show a close spatial relationship to the dunitic sills, and are interpreted as differentiates of the sills. In one exposure,

OGS 10 405

Photo 34–Coarse-grained (pegmatoidal) texture of quartz gabbro forming narrow differentiate at top of dunitic sill near former Bowman Mine.

the gabbro forms a 2 m thick dike intrusive into the peridotite. The colour index of the gabbro is about 40 percent and consists almost entirely of saussuritized plagioclase and actinolitic hornblende.

Chemistry of Ultramafic and Mafic Intrusive Rocks

Most of the chemical data on the ultramafic and mafic intrusive rocks is taken from T.L. Muir (1975), and the analyses are reproduced on microfiche (*see back pocket*). Also included are some of the writer's samples, and those of Naldrett (1966).

The ultramafic intrusive rocks and related differentiates display chemical trends similar to those of the komatiitic and Mg-tholeiitic volcanic rocks. Perhaps the most noteable feature of the ultramafic intrusive rocks is the high magnesium content; MgO averages about 43 percent in the intrusive ultramafic rocks versus about 30 percent in the extrusive ultramafic rocks. This one chemical parameter, at least in the Timmins area, is often sufficient to correctly categorize an ultramafic rock as either intrusive or extrusive. This is readily seen

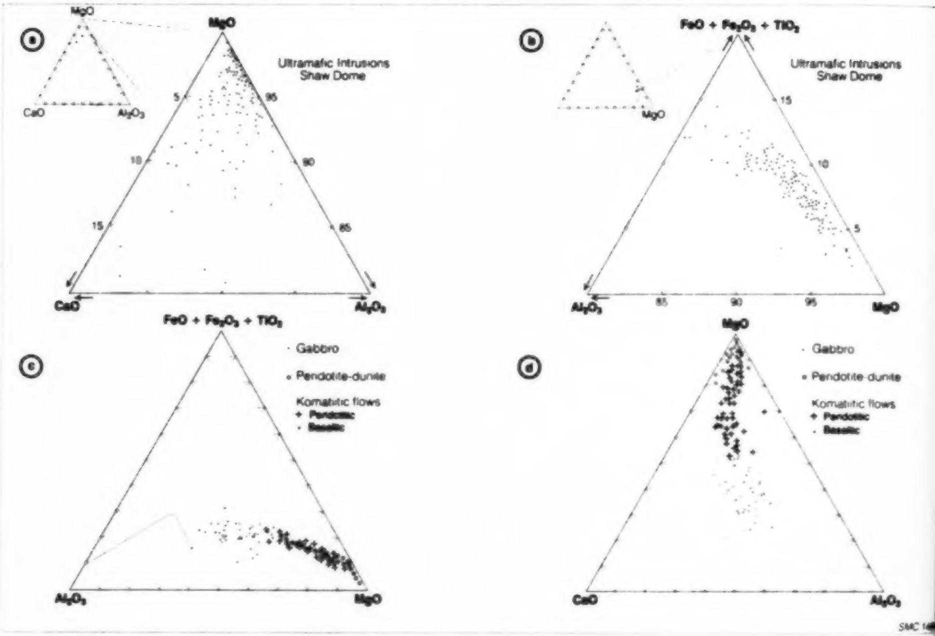


Figure 12a–CaO-MgO-Al_2O_3 diagram of ultramafic intrusions in the Shaw Dome.

Figure 12b–Al_2O_3-(FeO + Fe_2O_3 + TiO_2) - MgO cation diagram of ultramafic intrusive rocks from the Shaw Dome.

Figure 12c–Al_2O_3-(FeO + Fe_2O_3 + TiO_2) - MgO diagram showing relationship between mafic and ultramafic intrusions and komatiitic flows.

Figure 12d–CaO-MgO-Al_2O_3 diagram showing relationship between mafic and ultramafic intrusions and komatiitic flows.

in Figures 12c and 12d where there is only minor overlap in composition, whereby the basal cumulate parts of some flows extend into the compositional range dominated by the dunites.

Compositionally, the pyroxenite, pyroxene-hornblendite, and gabbro differentiates associated with the dunites span the fields of peridotitic and basaltic komatiites (Figures 12c and 12d) and extend into the field of Mg-tholeiitic basalt. The identical compositions exhibited by the intrusive differentiates and the volcanic rocks suggest there is a genetic relationship between the two. Namely, the komatiitic volcanic rocks and at least some of the Mg-tholeiites probably represent late stage differentiates derived from the dunitic sills. Some form of filter pressing could be invoked to remove the largely liquid fractions from the sills. Also in support of this close genetic relationship is the proximity of the sills and flows, and the fact that the flows are always stratigraphically above the sills.

FELSIC INTRUSIVE ROCKS

A variety of felsic intrusive rocks occurs in the area and appears to span an age of emplacement from synvolcanic to late tectonic. The oldest are considered to be the soda-rich quartz-feldspar porphyries and trondhjemites; the youngest, the more potassic granodiorites and monzonite. In general, this age relationship reflects an increasing K/Na ratio with decreasing age, similar to that reported in many Archean terrains (Viljoen and Viljoen 1969a,b, and c, Anhaeusser 1973; Glikson 1971). Reversals do occur, however (Ayres 1977), and in the adjacent Watabeag River Area (Pyke 1976), for example, a small stock of granodiorite intrudes the Bradley Lake syenite. Contact relations between various plutons, however, are rarely observed, and ages are necessarily inferred from relationships with the surrounding country rocks and the structures within the plutons. In the Timmins area, it is the author's opinion that all the soda-rich plutons predate the potassium-rich plutons; age relationships within either group are at best tentative.

Quartz-Feldspar Porphyries

Many of the porphyries are located in Tisdale Township where they have been discussed at some length by A.R. Whitman (1927), J.E.L. Evans (1944), E.S. Moore (1953), and Ferguson *et al.* (1968).

The porphyries are light grey to buff weathering, moderately to strongly foliated, and light grey to light green grey on fresh surfaces.

Phenocrysts of quartz, rarely as large as 5 mm and averaging 1 to 2 mm in diameter are a conspicuous feature and generally form 2 to 6 percent by volume of the rock. Phenocrysts of albitic plagioclase are subhedral in shape, invariably twinned, form 30 to 60 percent by volume of the porphyry, range in size from 0.5 to 5 mm and average approximately 1 to 2 mm. All the plagioclase phenocrysts contain extremely fine dust-like particles which impart a cloudy appearance to the grains; in addition, alteration to sericite is common and shows all variations from incipient development along cleavage planes to virtually complete replacement of the grains. The groundmass is a mesostasis of fine untwinned albite and lesser amounts of quartz. Fine flakes of sericite are dispersed throughout the matrix and impart a strong foliation to the rock. Chlorite and calcite are common as small, 2 to 3 mm in length, randomly distributed, irregular-shaped patches. Common accessories include chlorite, pyrite, calcite, actinolite, leucoxene, and apatite. Evans (1944) who did a detailed study of the porphyries also reported traces of fuchsite, ilmenite, titanite, rutile, carbon, and scheelite. In addition, the Pearl Lake porphyry at the McIntyre Mine contains gypsum and anhydrite which has locally replaced large sections of the porphyry (Ferguson *et al.* 1968).

The porphyries all occur within the lower formation of the Tisdale Group. Restriction to this stratigraphic interval suggests to the author that some or all of the porphyries may largely represent rhyolitic domes formed on the surface. This may also help explain the dovetailing or interfingering of the ends of the porphyry and enclosing rocks as reported by Evans (1944).That some of the porphyries may be extrusive, at least in part, would also assist in explaining the apparent lack of offsets across contacts "intruded" by the porphyry, and the absence of evidence for forceful intrusion as noted by Evans (1944). A more detailed study of Mt. Logano in northeast Shaw Township may aid in interpretation, as this is perhaps the best exposed porphyry in the area. Here, the central part of the porphyry is only weakly to moderately foliated, and there is no evidence of any fragmental texture. Towards the margins of the porphyry, the foliation steadily increases until the rocks become so strongly fissile that it is difficult to discern whether the outcrops are the sheared margin of the porphyry or the adjacent crystal tuffs. Conceivably, the sheared rocks peripheral to the more massive porphyry could represent a brecciated and fragmented margin of a rhyolitic dome. In any event, if the porphyries are not in part extrusive rocks, there can be little doubt that they are high level (epizonal) intrusions of subvolcanic derivation. M.E. Hurst (1936) was the first to point out the subvolcanic affinity of the porphyries, and suggested that some may represent vents from which the felsic pyroclastic rocks were erupted, notably the Krist fragmental.

Trondhjemite

A small stock of trondhjemite and minor satellitic intrusions occur on the south side of the Shaw Dome in Eldorado and Langmuir Townships (Pyke 1970, 1975b). The trondhjemite is medium grained, equigranular, weakly foliated, light grey on fresh and weathered surfaces, and shows little variation in composition. Modal analyses of 12 samples taken from Pyke (1970, 1975b) give an average composition of 61 percent plagioclase, 27 percent quartz, 2 percent hornblende, 2 percent biotite, 4 percent epidote, and minor amounts of sphene, chlorite, sericite, and apatite. Traces of one or more of magnetite, pyrite, calcite, zircon, and rutile are present in a few of the samples examined. The texture is hypidiomorphic granular with an average grain size of 1.5 to 2.0 mm.

Quartz Diorite, Diorite

The felsic intrusive rocks in the southwestern corner of the area (Thorneloe and Price Townships) are provisionally mapped as diorite and quartz diorite. Only a few outcrops near the eastern periphery of the body were examined at the time of mapping, and these were mainly quartz diorite to diorite in composition, similar to some of the dioritic phases marginal to the Peterlong Lake Complex to the south (Pyke 1977). As shown by Pyke *et al.* (1973), these felsic intrusive rocks in the southwest part of the Timmins area probably form part of the northern margin of the large batholithic complex lying to the southwest of the map-area. Although the published information on this batholith is minimal and confined to a few small areas at the margins (Milne 1972; Bright 1974; Pyke 1977), additional unpublished data of the author would suggest that much of the batholith is trondhjemitic.

Granodiorite

Granodiorite is the most abundant intrusive rock in the area, and most of this is confined to a large stock, the Adams Granodiorite (Pyke 1975b), in the southwestern part of the area. Granodiorite also forms a number of sill-like intrusions and small plugs in Whitney Township, and small stocks in central Deloro Township and south-central Ogden Township. Minor small scattered intrusions occur elsewhere throughout the area.

Granodiorites in Whitney and Deloro Townships

In Whitney Township, intrusions of granodiorite are confined to the felsic pyroclastic sequence in the southern part of the township. Most intrusions occur as sill-like intrusions up to approximately 500 m in outcrop width, and are best exposed in the area south of Bob's Lake. The granodiorite is medium grained, massive to weakly foliated, white weathering, and light grey to pinkish grey on fresh surfaces. Chilled margins are well exposed near Bob's Lake, and narrow apophyses intrude the adjacent felsic tuffs. Locally, numerous dikes of quartz and aplite intrude the granodiorite and probably represent associated late stage differentiates. Four thin sections of the granodiorite were examined and showed little variation in composition, averaging 55 percent albitic plagioclase, 17 percent microcline, 20 percent quartz, 4 percent biotite, 1 percent muscovite and minor chlorite, epidote, sphene, apatite, and traces of pyrite. Muscovite is preferentially developed at the margins of the sills. The texture is hypidiomorphic granular tending to be weakly porphyritic. Average grain size is 1 to 2 mm.

A small stock of similar composition and texture outcrops in lot 8, concession I, Whitney Township, approximately 4 km northwest of Mt. Logano. Numerous quartz veins and blebs form up to 15 percent by volume of the eastern part of the stock. The granodiorite contains a few small mariolitic cavities and is locally porphyritic containing 2 to 5 percent quartz and feldspar phenocrysts up to 3 mm. The north boundary of the stock is marked by a shear zone of chloritized and carbonitized volcanic rocks dipping steeply (60°) toward the granodiorite, and penetrated by a number of quartz veins, one of which partly follows the north contact of the stock. The south boundary of the stock is not as easily delineated as some of the well-foliated quartz sericite rocks could be interpreted as schistose equivalents of the granodiorite. However, for consistency these schistose varieties have been included with the felsic tuffs.

A small elliptical stock approximately 100 by 250 m outcrops about 1.5 km northwest of the previously described stock and is in lot 9, concession II. The stock contains about 10 percent combined feldspar (albite and microcline) and quartz phenocrysts 2 mm in size, set in a fine-grained (0.2 mm) leucocratic (2 - 3 percent biotite and chlorite) matrix of granodiorite. Quartz veins and blebs are common; two prominent quartz veins up to 1.7 m thick trend northwest across the outcrop. Locally, minor tourmaline and carbonate form small cavity fillings in the stock. Other small irregular bodies of granodiorite are common in the vicinity, notably 400 m west of the stock, but are too small to incorporate on the map.

A poorly exposed small stock of pink to light grey weathering, fine- to medium-grained granodiorite outcrops west of McKay Lake in central Deloro Township. One thin section was examined and contained 65 percent saussuritized plagioclase, 19 percent quartz, 8 percent potassic feldspar, 7 percent hornblende largely altered to chlorite and traces of apatite, magnetite, and sphene.

Adams Granodiorite

The Adams Granodiorite has been previously described by Pyke (1975b, 1978b), and underlies most of Adams Township, the southwestern corner of Eldorado Township, and a large part of the adjoining townships of Price, McArthur, and Douglas. The granodiorite was emplaced entirely within the upper volcanic sequence (Tisdale Group), and is interpreted to be a late tectonic intrusion on the basis of the weak foliation and the conformability of the contact of the stock with the stratigraphy in the surrounding volcanic rocks. The granodiorite is medium grained, massive to very weakly foliated, and light greyish white to pink on weathered and fresh surfaces. Phenocrysts of potassic feldspar form 8 to 15 percent by volume of the rock, range in size from 3 to 25 mm, and average approximately 8 mm. There is little variation in composition throughout the stock. Seven thin sections (Pyke 1975b) gave an average composition of 61 percent plagioclase, 10 percent microcline, 20 percent quartz, 3 percent hornblende, 2 percent biotite, and minor to trace amounts of epidote, chlorite, magnetite, sphene, apatite, pyrite, and zircon.

A much smaller yet similar stock of granodiorite occurs in south-central Ogden Township, and is possibly a satellitic intrusion of the Adams Granodiorite.

Monzonite

Part of a small stock of medium-grained, pink, porphyritic monzonite extends into the southeast corner of the area. In general, many of the exposures, especially toward the southern contact, vary greatly in texture and composition (colour index of 5 to 60 percent), suggest extensive contamination, and perhaps indicate that much of the exposure may be relatively close to the roof of the intrusion. Locally, a highly contaminated marginal zone of pyroxene-amphibolite is extensively developed, particularly along the northern contact where the monzonite intrudes ultramafic volcanic rocks.

Eight thin sections were examined from throughout the stock (Pyke 1973), each representing what were considered to be relatively uncontaminated fractions at a given locality. The following modes were established: plagioclase 36 to 56 percent (average 43 percent), potassic feldspar 21 to 48 percent (average 34 percent), hornblende 5 to 25 percent (average 14 percent). Minor constituents include one or more of the following; clinopyroxene, quartz, biotite, magnetite, chlorite, epidote, sphene, leucoxene, calcite, apatite, and allanite. Three thin sections of pyroxene amphibolite gave an average composition of 43 percent hornblende, 33 percent clinopyroxene, 11 percent oligoclase, 5 percent chlorite, 3 percent magnetite, 2 percent apatite, and minor sphene, epidote, calcite, and quartz.

An isolated occurrence of coarse-grained pyroxene amphibolite occurs in the northeast corner of Douglas Township (Pyke 1978b). The rocks are very similar in appearance to those bordering the monzonite in Langmuir and Fallon Townships; colour index 40 to 84 percent, coarse grained (hornblende crystals up to 12 mm in length), and intruded by minor dikes of monzonite. It was inferred (Pyke 1978b) that the pyroxene-amphibolite reflects the near surface expression of an underlying body of monzonite.

Chemistry of the Felsic Intrusive Rocks

The chemical analyses of the felsic intrusive rocks in the Timmins area are given in Table X (*see* microfiche sheets in back pocket). Most of the analyses show a low K/Na ratio ranging from about 0.2 to 0.6, the granodiorites tending toward the higher values. Little can be said from the limited chemical data other than that the overall low K/Na ratio reflects limited fractionation within the felsic intrusive rocks. This in turn may reflect a close genetic relationship between volcanism and plutonism.

Early, Middle, and Late Precambrian

MAFIC INTRUSIVE ROCKS

Diabase

The diabase dikes are subdivided into three different age groups; Early, Middle, and Late Precambrian. The basis for this subdivision has previously been given by Pyke (1970, 1973, 1975a, b, and c) and was also utilized by Pyke *et al.* (1973) for this part of the Abitibi Belt. Dating of the majority of the dikes from field evidence such as cross-cutting relationships, structural displacements and age relative to Middle Precambrian sedimentary rocks is commonly lacking. Therefore, the three-fold subdivision for many of the dikes is largely based on indirect evidence.

North-trending diabase dikes in this part of the Superior Province are generally referred to as being part of the Matachewan Swarm (Fahrig *et al.* 1965) and are assigned an Early Precambrian age (Fahrig and Wanless 1963). However, the recent compilation in the Timmins - Kirkland Lake area (Pyke *et al.* 1973) illustrates that there are possibly two major swarms of north-trending dikes in the western half of the area: (1) the Matachewan-type diabase dikes centred near the town of Matachewan, and (2) diabase dikes which trend north-northwest in the southern part of the area, for example near Shining Tree, and then swing to a more northerly strike further north. The latter swarm would correspond to the dikes for which Middleton (1969) did remnant magnetism studies in the Kamiskotia area and A.V. Leech (1965) dated in the Timmins area. Middleton found that the north-trending dikes had magnetic properties similar to the Abitibi dikes (Fahrig *et al.* 1965) of Late Precambrian age. Furthermore, Leech (1965), as reported by Ferguson (1968), found no Early Precambrian ages (potassium-argon whole rock method) for the north-trending dikes sampled; one dike in Keefer Township trending N5°W gave an age of 1930 my, and three dikes in Bristol Township trending N35°W, N20°W, and N35°W gave ages of 1760 my ago, 1500 my ago, and 1325 my ago respectively. Nevertheless, some north-trending diabase dikes in the Timmins area are probably of Early Precambrian (Archean) age, particularly near the eastern boundary. For example, in Fallon Township, (Pyke 1973) northerly trending diabase dikes are unconformably overlain by Middle Precambrian sedimentary rocks of the Cobalt Group, and these same dikes extend northward into Langmuir Township. Therefore, the relative age of a dike is by no means implicit in its trend. Leech also reported an age of 1220 my for a N5°W trending diabase dike in Taylor Township 50 km east of Timmins. Nevertheless, a combination of trend and petrography may be useful in distinguishing the ages of a large number of diabase dikes. For example, to date no careful studies have been done on the composition of the diabase dikes in conjunction with age dating. It is not unusual to find two parallel north-striking diabase dikes separated by perhaps 15 to 90 m, in which one is olivine bearing and the other is quartz bearing. It is the author's contention that these differing compositions may reflect significant age difference, as does the mineralogy in northeast-trending dikes. Therefore, even though a certain dike trend may largely represent a particular swarm, parallel fractures may have formed, and filled with diabase, during the emplacement of any of the other dike sets (Figure 13). Nevertheless, in the map with this report, all northerly trending dikes are assigned an Early Precambrian age, with the reservation that some are probably much younger.

Reference to compiled maps of the Ontario Division of Mines by L.D. Ayres *et al.* (1971) and Pyke *et al.* (1973), shows that there are two differing trends of northeasterly-striking diabase dikes in this part of the Superior Province. One set trends northeast, the other set trends east-northeast. The most southerly of the northeasterly trending dikes in the Timmins area form part of the former trend. There are a number of north-striking faults in this part of the Abitibi Belt (Ayres *et al.* 1971; Pyke *et al.* 1973) and the northeast-trending dikes show a much greater displacement along many of these faults than do the east-northeast-trending dikes (*see* Figure 13). This implies that the northeast-trending dikes are the older of the two sets. Also, the northeast-trending set cuts the Lower Huronian sedimentary rocks in Cleaver and Fallon Townships (Pyke *et al.* 1973) which places the age of these dikes at post early Middle Precambrian; perhaps the same age as the Nipissing Diabase 2170 my (Krogh and Davis

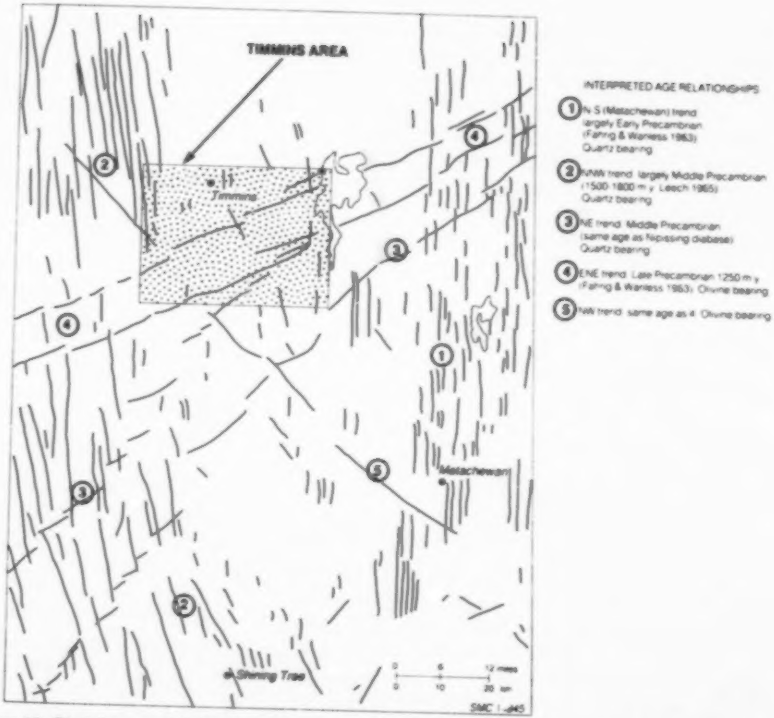

TIMMINS AREA
Timmins
Matachewan
Shining Tree
INTERPRETED AGE RELATIONSHIPS
① N-S (Matachewan) trend largely Early Precambrian (Fahrig & Wanless 1963) Quartz bearing
② NNW trend largely Middle Precambrian (1500-1800 m.y. Leech 1965) Quartz bearing
③ NE trend Middle Precambrian (same age as Nipissing diabase) Quartz bearing
④ ENE trend Late Precambrian 1250 m.y. (Fahrig & Wanless 1963) Olivine bearing
⑤ NW trend same age as 4 Olivine bearing
0 6 12 miles
0 10 20 km
SMC 1..845

Figure 13–Sketch map of diabase dike trends in the Timmins-Matachewan area (from Ayres *et al.* 1971).

1974). The east-northeast-trending diabase dikes form part of the Abitibi Swarm (Fahrig *et al.* 1965), and are Late Precambrian having an age of 1230 my (Fahrig and Wanless 1963). Northwest-trending olivine diabase dikes are perhaps of a similar (i.e. Late Precambrian) age (Pyke 1978a and b).

Brief descriptions of the diabase dikes are discussed as follows in chronological order.

EARLY PRECAMBRIAN

There is a general paucity of north-trending diabase dikes in the Timmins area; most are confined to the extreme east or west margins of the map-area. This general zone of dike depletion is evident in Figure 13 between swarm 1 and 2.

The diabase is massive, and weathers brown to orange-brown, and rarely forms dikes greater than 30 to 46 m thick. Fresh surfaces are dark grey, and both olivine- and quartz-bearing varieties occur in the Timmins area. Semiequant phenocrysts of light green saussuritized plagioclase, averaging about 3 to 8 mm in length are common in some of the dikes. Phenocrysts larger than 8 mm generally represent an aggregate of plagioclase crystals and form a glomeroporphyritic texture.

Seven thin sections were examined from Langmuir and Eldorado Townships; only one of the dikes contained minor olivine, the others contained traces to 6 percent quartz. Plagioclase (labradorite) forms from 50 to 65 percent of the rock, and clinopyroxene from 25 to 40 percent. Other constitutents include magnetite (average 4 to 5 percent), minor apatite, pyrite, traces of zircon and minor secondary hornblende, epidote, chlorite, leucoxene, biotite, and calcite.

MIDDLE PRECAMBRIAN

Quartz Diabase

A large dike of quartz diabase, interpreted to be of Middle Precambrian age, provides a relatively continuous series of well-exposed outcrops across the southeastern part of the area. Outcrops weather grey, brown or brownish orange, and generally vary from dark to medium grey on fresh surfaces, although in the coarse-grained central part of the dike, some of the feldspars impart a light pinkish hue to the rock. Locally, minor fine-grained pink granophyre intrudes the diabase, and is interpreted to be a differentiate of the diabase.

Modal analyses of a number of samples are given by Pyke (1970, 1975a, b, and c). Colour index varies from 30 to 50 percent. Augite is the dominant mafic mineral, and shows minor to complete alteration to hornblende, lesser chlorite, and traces of biotite. Quartz forms 2 to 11 percent by volume and magnetite 3 to 6 percent. Apatite and zircon are common accessories.

A diatreme, tentatively thought to be associated with the quartz diabase, intrudes the trondhjemite and quartz diabase in northeastern Eldorado Township (Pyke 1975b). Inclusions in the diatreme form approximately one-third of the rock and consist largely of trondhjemite and minor diabase and granodiorite. The matrix is lamprophyric consisting of 30 to 40 percent phenocrysts (0.6 mm in length) of olivine and augite largely altered to serpentine and chlorite.

LATE PRECAMBRIAN

Olivine Diabase

Two large dikes of olivine diabase traverse the area in an east-northeast direction. The most southerly dike appears to have been emplaced in an *en echelon* manner with the zone of overlap of two diabase-filled fractures being in the area of northern Eldorado Township. This relationship is perhaps best seen on Map 2205 (Pyke, Ayres, and Innes 1973).

Weathered surfaces are grey to orange brown, but generally have a somewhat darker shade than is characteristic of the quartz diabase. In some outcrops, a thin accumulation of grus has formed on the surface and much of the overlying rock is very friable and readily crumbles when struck with a hammer.

Modal analyses of five specimens (Pyke 1975b) gave an average composition of 73 percent plagioclase, (labradorite), 6 percent augite, 14 percent olivine, 4 percent magnetite and minor apatite, chlorite, and biotite.

Middle Precambrian

HURONIAN SUPERGROUP

Cobalt Group

GOWGANDA FORMATION

A high ridge, 75 to 90 m of relatively flat lying, unmetamorphosed sedimentary rocks of the Gowganda Formation, Cobalt Group, extends into the southern part of the area in Fallon Township. In addition, two small outliers outcrop on the Langmuir-Fallon township boundary. These sedimentary rocks have previously been described by Pyke (1970, 1973) and consist of interlayered argillite, arkose, wacke, and conglomerate in approximately the following proportions: argillite, (35 percent); arkose, (45 percent); wacke, (10 percent); polymictic pebble and boulder conglomerate (10 percent).

Cenozoic

QUATERNARY

Pleistocene and Recent

A thick mantle of proglacial lacustrine silt, clay, and fine sand, deposited in glacial Lake Barlow-Ojibway (Stockwell 1957, p. 480) mantles much of the area, particularly the townships of Eldorado, Langmuir, Cody, eastern Whitney, and the southern parts of Deloro and Shaw. This relatively impervious clay-rich blanket inhibits drainage and extensive areas of muskeg are common (*see* Photo 3). Diamond drilling (Assessment Files Research Office, Ontario Geological Survey, Toronto) indicates that the average thickness of these sediments is 9 to 12 m; their maximum thickness is about 38 m.

Glaciofluvial deposits of sand and gravel extend along the western part of the area near the Deloro-Ogden and Price-Adams township boundaries. Wind blown dunes are a prominent feature of the landscape in northwestern Deloro Township.

STRUCTURAL GEOLOGY

The structure of the area is exceedingly complex and still awaits rigorous analysis. The current survey, coupled with previously existing knowledge of the area, serves to outline some of the broader or more regional aspects. Because of the interdependence of structure and stratigraphy, modifications in the structural interpretations will necessarily somewhat alter the stratigraphy, particularly in estimating thicknesses of strata due to repetition by undetermined folding or faulting.

Faults

The Destor-Porcupine Fault (*see* Figure 2) separates the Timmins area into two main structural domains: (1) the area north of the fault which encompasses the main gold mining camp, and (2) the area south of the fault. Even though only a small segment of the Destor-Porcupine Fault traverses the area, it is the author's opinion that this fault represents a fundamental fracture in the Early Precambrian crust. The fault extends at least as far west as the Kukatush area (Milne 1972) and probably as far as the Kapuskasing Structure. Eastward, the fault has been traced as far as the Noranda area (Wilson 1949; Dimroth *et al.* 1973; Gelinas *et al.* 1977) where it merges with the Cadillac Break which is the eastward extension of the Larder Lake Break (Thomson 1948) in the Kirkland Lake area. The Cadillac Break extends eastward to the Grenville Front, approximately 65 km east of Val D'Or. The Destor-Porcupine Fault is therefore part of a major east-west fracture zone probably extending from the Kapuskasing Structure to the Grenville Front, a distance of approximately 440 km. Conceivably, the fault was of much greater extent in the Early Precambrian as it is terminated at either end by younger fault systems.

Within the Timmins area, the main shear zone of the Destor-Porcupine Fault is at least 150 m wide, and is intimately associated with ultramafic volcanism and sedimentation throughout much of its length. This is also true for much of the fault zone throughout its regional extent, and will be discussed in more detail in the regional synthesis presented at the end of this report.

Within the Timmins area, the Destor-Porcupine Fault Zone dips steeply north, (80 degrees, Lane 1968) to near vertical. The amount or direction of movement along the fault zone is unknown, however, some inferences regarding stratigraphic relationships and displacement can be made:

(1) A continual stratigraphic sequence can be traced across the fault

zone, the lower formations of the Tisdale Group being in juxtaposition on either side of the fault (that is, south of the Buffalo Ankerite and Aunor Mines). This implies that the ultramafic rocks on either side of the fault are coeval and that the Deloro Group is definitely older than the Tisdale Group, as mentioned previously; this was always suspected in the Timmins camp (Dunbar 1948; Hogg 1950; Ferguson *et al.* 1968).

(2) The relative vertical movement is south side up, north side down as the older strata are exposed on the south side of the fault.

(3) The strike-slip component of the fault is one of left-lateral movement as given by the positioning and symmetry of the Porcupine Syncline and Whitney Anticline.

(4) The abundance of ultramafic volcanic rocks along and in proximity to the Destor-Porcupine Fault suggests to the author that the fault provided a main fissure up which much of the ultramafic magma moved from a source zone within the mantle.

Some sedimentary rocks are stratigraphically equivalent to, and overlie the ultramafic rocks along the fault zone. This would further support the concept of the fault representing a tectonically unstable and active zone throughout much of the Archean, in that sedimentation processes could be expected to be active along such a zone. Alternatively, one could argue that the fault formed later than the ultramafic volcanic rocks as this would be a likely zone for a fault to be initiated. The author considers this highly unlikely when viewed in a regional context, as ultramafic volcanism can be demonstrated to have occurred virtually along the entire 440 km extent of the fault zone, which itself represents a linear element. If the fault zone is not invoked as a volcanic fissure, then numerous ultramafic sources must be called on to supply relatively synchronous ultramafic volcanism along a linear belt. This is so unlikely that it must be ruled out as an alternative.

Other younger, yet regionally important faults also traverse the area; notably the Montreal River Fault, and the Burrows-Benedict Fault. The Montreal River Fault forms part of the Ottawa-Bonnechere Fault System (Kumarapeli and Saull 1966); one branch of the system extends northeast from Mattawa through Lake Temiskaming, another branch extends east from Mattawa through Lake Nipissing (Kumarapeli and Saull 1966; Lovell and Caine 1970). The Montreal River Fault is parallel to and associated with the western boundary faults of the Cobalt Graben (Wilson 1949; Lovell and Caine 1970) which form the northeast extensions of the Ottawa - Bonnechere Fault System through Lake Temiskaming.

The Burrows-Benedict Fault trends north-northeast across the Timmins area and merges with the Montreal River Fault near the west-central boundary of Tisdale Township. This fault displaces the Destor-Porcupine Fault approximately 1.5 km in a left-lateral sense. The Burrows-Benedict Fault is parallel to the Onaping Lineament (Wilson 1949), a series of north- to north-northeast-trending faults extending from the Sudbury Basin to the Kapuskasing Structure, and which form the western boundary of the Cobalt Plate or graben (Wilson 1949). The Burrows-Benedict Fault would be near the eastern boundary of the Onaping Lineament. Northward extending “fingers” of Cobalt sedimentary rocks from the main Cobalt Plate, which extends from approximately Matachewan southward to the Grenville Front, possibly occupy fault zones associated with the Onaping Lineament. One such zone of Cobalt extends into the southeast corner of the Timmins area. The Burrows-Benedict Fault appears to merge with the Montreal River Fault in the Timmins area, but more regionally, as is shown on Ontario Division of Mines, Maps 2205 and 2197, the northerly trending Onaping Lineament tends to transect the northeast-trending Montreal River Fault Lineament. This same relationship is shown by H.L. Lovell and T.W. Caine (1970).

Folds

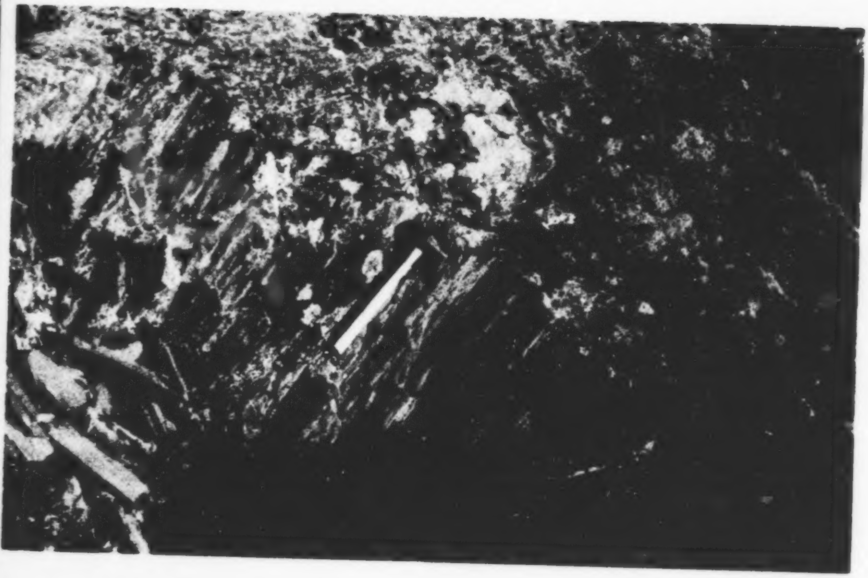
FOLD STRUCTURE NORTH OF THE DESTOR-PORCUPINE FAULT

North of the Destor-Porcupine Fault, the structure is best known in Tisdale, Deloro, and Whitney Townships as a direct result of the extensive mapping which ensued in and close to the areas surrounding the major gold discoveries and producers. A.G. Burrows (1911, 1924) was the first to outline many of the major fold and fault structures in this area; this data was subsequently built on by a number of workers (Hurst 1936, 1939; Dunbar 1948; Hogg 1950; Ferguson 1959a, b, c, d, and e; Graton *et al.* 1933; Buffam 1948a and b). Lack of exposure in Mountjoy Township, the north half of Ogden Township, and the eastern part of Bristol and Jamieson Townships, precludes all but a very generalized interpretation for the northwestern part of the Timmins area.

One of the dominant structures north of the Destor-Porcupine Fault is the Porcupine Syncline, the axial trace of which trends approximately east-west across the south half of Tisdale Township. A strong penetrative lineation (Photo 35) accompanied the development of this syncline and is a prominent feature in virtually all the outcrops of the main gold mining camp in south Tisdale and north Deloro Townships. The lineation is manifested by an extreme elongation as displayed by pillows, variolites, amygdules, fragments, mineral streaking, and porphyry bodies. In addition, cleavage intersections and bedding-cleavage intersections conform to the plunge of the syncline. Figure 14a is a stereographic projection of the lineations and poles to axial plane cleavage in the core and nose area of the syncline as measured in the metavolcanics. This indicates a plunge to the syncline in the central core area of the fold of approximately azimuth 090 degrees at an angle of 45 degrees (Figure 14b).

Commonly two cleavages are evident in most outcrops and in a few, three distinct cleavages can be discerned. The most prominent cleavage is subparallel to the layering (stratigraphy) on the limbs of the fold and generally strikes approximately 75 to 85° on the north limb of the syncline (*see* Figure 16b) and approximately 110° to 120° on the south limb of the syncline (Figure 15). Dips are steep (70° to vertical), and generally dip inward toward the axial plane of the main syncline.

In many outcrops, the cleavage is commonly seen to be of a conjugate type in that it consists of two subparallel cleavages intersecting at an angle of 20 to 30°; generally one of the cleavages is preferentially developed in differing outcrop areas. Rarely three cleavages are present, and where observed, generally



OGS 10 406

Photo 35–Eastward plunging lineation (varioles and hornblende) in pillowed Fe-tholeiitic basalt. Central Tisdale Township.

strike within an arc of no greater than approximately 60° and commonly 40°. A good example of this is in the Paymaster porphyry exposed in a roadcut north of Simpson Lake in southeast Tisdale Township. The development of more than one cleavage, and difficulty in confidently discerning each cleavage in differing outcrops, undoubtedly accounts for some of the spread as shown in Figures 14a and 14b. It has not been established whether all these essentially subparallel cleavages are related to the development of the Porcupine Syncline; however, the author suspects they are, as no folded cleavages were discerned in the nose area of the syncline.

The South Tisdale Anticline is located south of the Porcupine Syncline (*see* Figure 15). Many of the linear elements associated with this anticline also plunge in an easterly direction (*see* Figure 14b), even though the major fold itself plunges approximately vertical as is given by the layering in the metavolcanics. Apparently, the deformation accompanying the development of the Porcupine Syncline was of such intensity as to align the small scale linear elements into an easterly plunge to conform with the major syncline, even though the anticline has a differing plunge. No conclusive evidence was found to indicate an earlier or folded lineation within the anticlinal structure.

Near the nose of the South Tisdale Anticline, on the power line west of MacDonald Lake, the plunge of the variolites in the V8 basalt reverses, and the

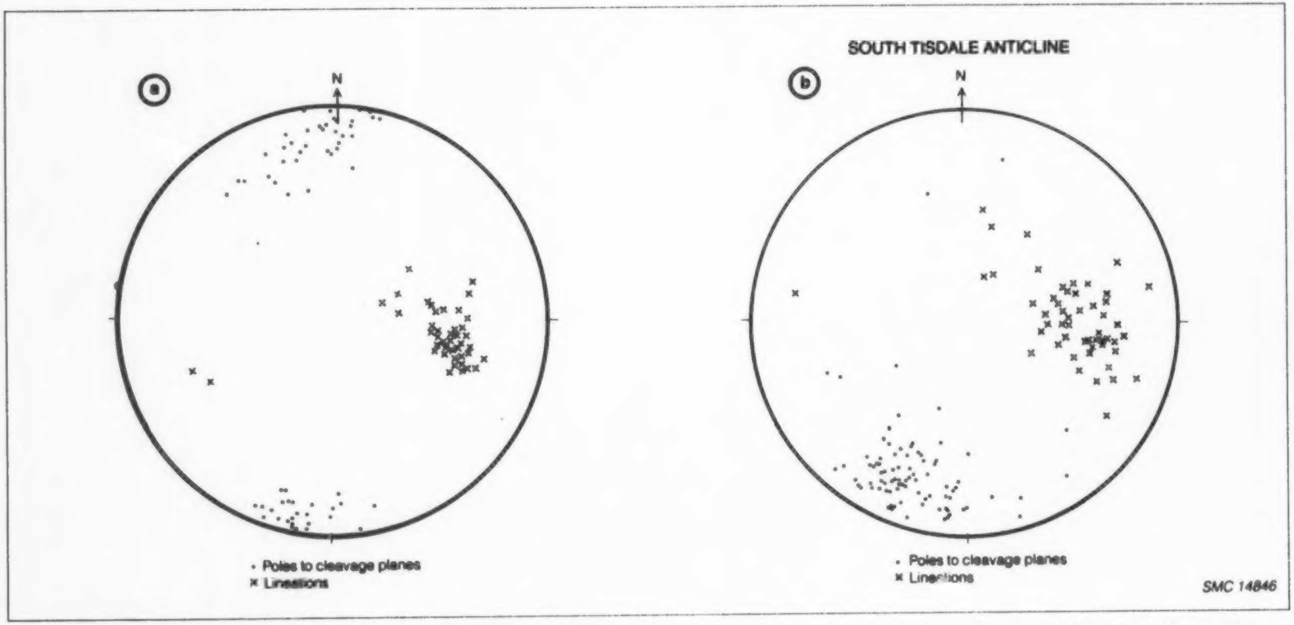


Figure 14a–Stereographic projection of the cleavage planes and lineations from the nose of the Porcupine Syncline in the vicinity of the Hollinger Mine.

Figure 14b–Stereographic projection of the structural elements from the South Tisdale Anticline.

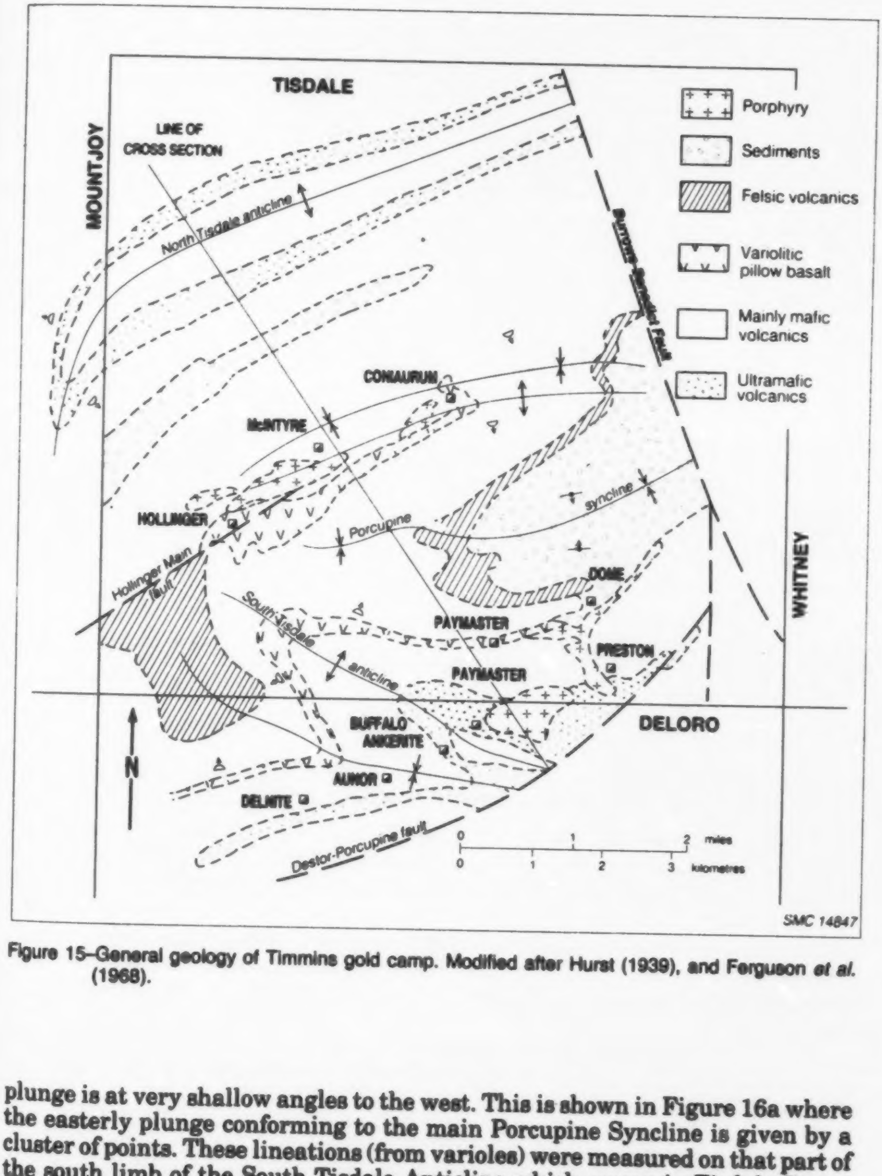

TISDALE
MOUNTJOY
LINE OF CROSS SECTION
North Tisdale anticline
Burrows-Benedict Fault
Porphyry
Sediments
Felsic volcanics
Variolitic pillow basalt
Mainly mafic volcanics
Ultramafic volcanics
CONIAURUM
McINTYRE
HOLLINGER
Porcupine
syncline
Hollinger Main fault
South Tisdale anticline
DOME
PAYMASTER
PRESTON
PAYMASTER
BUFFALO ANKERITE
AUNOR
DELNITE
DELORO
WHITNEY
N
Destor-Porcupine fault
0 1 2 miles
0 1 2 3 kilometres
SMC 14847

Figure 15–General geology of Timmins gold camp. Modified after Hurst (1939), and Ferguson *et al.* (1968).

plunge is at very shallow angles to the west. This is shown in Figure 16a where the easterly plunge conforming to the main Porcupine Syncline is given by a cluster of points. These lineations (from varioles) were measured on that part of the south limb of the South Tisdale Anticline which occurs in Tisdale Township. The change in plunge of the varioles from east to west occurs in that part of the fold near the nose of the syncline west of MacDonald Lake in north Deloro Township. Furthermore, in this part of the fold where there is a change in

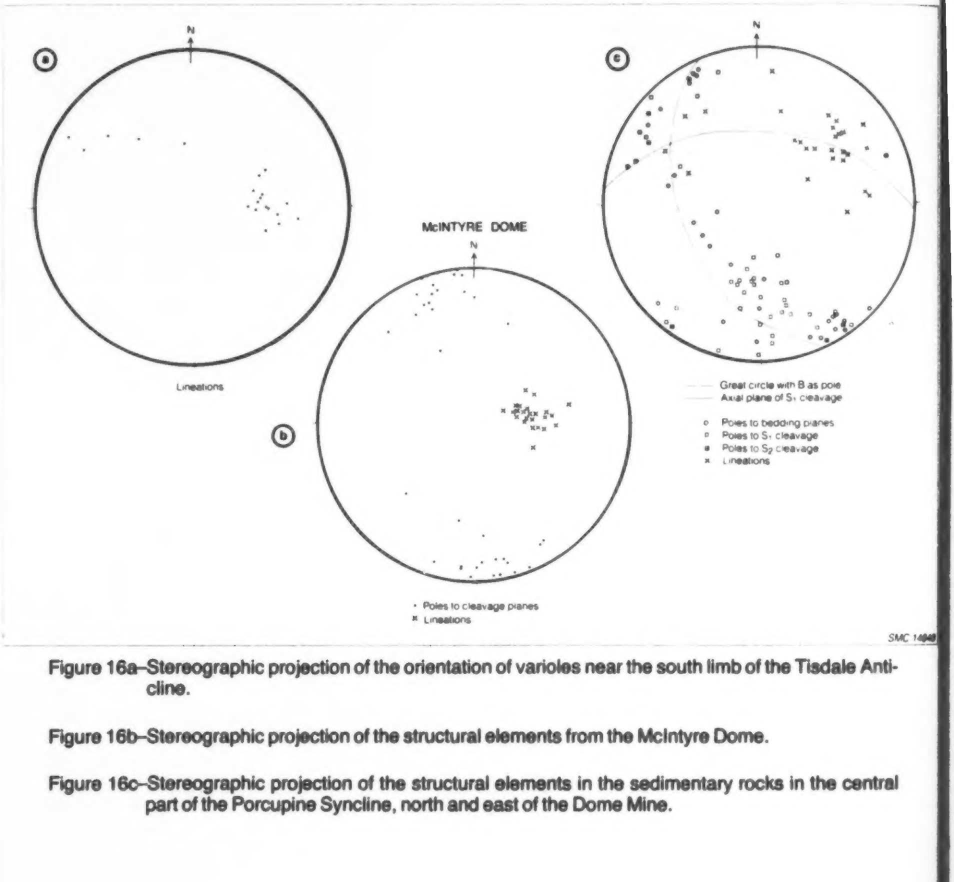

a
N
Lineations
McINTYRE DOME
N
b
Poles to cleavage planes
Lineations
c
N
Great circle with B as pole
Axial plane of S1 cleavage
Poles to bedding planes
Poles to S1 cleavage
Poles to S2 cleavage
Lineations
SMC 14949

Figure 16a–Stereographic projection of the orientation of varioles near the south limb of the Tisdale Anticline.

Figure 16b–Stereographic projection of the structural elements from the McIntyre Dome.

Figure 16c–Stereographic projection of the structural elements in the sedimentary rocks in the central part of the Porcupine Syncline, north and east of the Dome Mine.

the plunge of the varioles, there is also one outcrop which indicates an area of no strain as is shown by undeformed, circular varioles. This area of no strain would correspond approximately to that indicated by J.G. Ramsay (1967) for a fold structure.

Immediately north of the Porcupine Syncline in the vicinity of the McIntyre and Coniaurum Mines an elongated domal type structure (Ferguson *et al.* 1968) occurs; the axial plane trends east-northeast (*see* Figure 15). The domal structure is indicated by the outward-facing top determinations in the basaltic flows and the apparent closure of the V8 basalt at the periphery of the dome. Again, however, as in the case of the South Tisdale Anticline, the plunge of the minor structures is easterly, signifying in the author's opinion, the overprinting and strong deformation accompanying the development of the Porcupine Syncline. Figure 16b is a plot of the structural elements measured in this area.

OGS 10 407

Photo 36–Turbidite (layered greywacke-siltstone) in outcrop on east side of Dome tailing pond. Bedding (So) at 57/84S, Cleavage (S_1) at 74/56N. View looking northeast.

A comparison of Figures 14a, 14b, and 16a shows there is some scattering of the data. This, in the author's opinion, however, is not inconsistent with the interpretation of these minor structures having formed due to the same period of deformation.

The sedimentary rocks occupying the core of the Porcupine Syncline have two prominently developed cleavages. One, a slatey cleavage, is subparallel to layering (at an angle of 5 to 30 degrees to layering) and is extremely well developed in the argillaceous fraction of the turbidites (Photo 36). In the sandstone fraction, the comparable cleavage is present as a fracture cleavage; fractures are poorly developed and are commonly spaced at 32 to 10 cm intervals. The second cleavage is a closely spaced (3 mm or less) fracture cleavage that strikes 30 to 40° and displaces the slatey cleavage; the intersection of two cleavages produces a crenulation. This later fracture cleavage is interpreted to be a complimentary cleavage related to movement along the Burrows-Benedict Fault. Figure 16c illustrates the relationship between bedding, slatey cleavage, fracture cleavage, and lineations in the metasediments in the central part of the Porcupine Syncline.

A very open (wavelength-amplitude ratios of 7:1) north-south cross folding is evident in the southern part of Tisdale Township (Ferguson *et al.* 1968) and can be observed on some outcrops. The axial planes are near vertical and the plunge is approximately 60° in a north to northeast direction. This broad open folding would also account for some of the spread in the structural data shown in Figure 14a, 14b, and 16c.

The North Tisdale Anticline (*see* Figure 15) trends northeast across north Tisdale Township, the axial trace swings south near the Tisdale-Mountjoy Township boundary. The deformation is nowhere near as intense as that in south Tisdale Township; by comparison, the rocks in the northern part of the township are massive to weakly foliated. The same anticlinal structure is interpreted to extend eastward, across north Whitney Township, on the basis of a few scattered outcrops and available aeromagnetic data (GSC 1970). The attitude of a few pillowed flows, near the nose of the North Tisdale Anticline in Tisdale-Mountjoy Townships indicates that it plunges steeply north.

Figure 15 synthesizes much of the geology of the main gold mining camp in the Timmins area. As already discussed, the eastward-plunging Porcupine Syncline forms the dominant fold structure, and is flanked to the north and south by two main anticlinal structures which plunge steeply northwesterly to north. The reversal of plunge, and in particular the westerly direction of closure of all the folds can be explained by refolding, whereby an original north-trending series of folds was subsequently refolded about an east-west axis; this is shown diagrammatically in Figure 17. It is suggested that the earlier north-trending fold structure was largely recumbent, with closure to the west.

UNCONFORMITY ("KEEWATIN TEMISKAMING" RELATIONSHIP)

A major unconformity has been proposed between what has formerly been referred to as Keewatin sediments and Temiskaming sediments in the Timmins area (Hurst 1939; Ferguson *et al.* 1968). Part of the proposed contact between the two sedimentary sequences is marked by an angular unconformity and is best exposed approximately 0.8 km north of South Porcupine. Here, a conglomeratic bed approximately 70 m thick truncates an underlying turbidite sequence; the angular discordance is about 30°. From the author's observations and those of Lorsong (1975), it was found that minor structures in the truncated turbidites, the conglomerate, and overlying turbidites are the same, thus precluding any major tectonic unconformity. Detailed work by Lorsong (1975) strongly suggests that this, as well as other conglomeratic units represent lensoidal channel fills within the turbidite sequence. Nevertheless, there must have been some tectonic tilting before the deposition of the conglomerate and overlying sedimentary rocks; nowhere does the bedding in the upper sequence approach conformity with the lower sequence. As would be expected if it were only a simple channel filling relationship. Moreover, at least 1200 m of stratigraphy have been removed from the underlying older sedimentary rocks (Beatty formation) along the unconformity (see Map 2075, Ferguson *et al.* 1968). The major change in sedimentation north of South Porcupine is approximately 300 m higher in the stratigraphy than the above-mentioned unconformity, and oc-

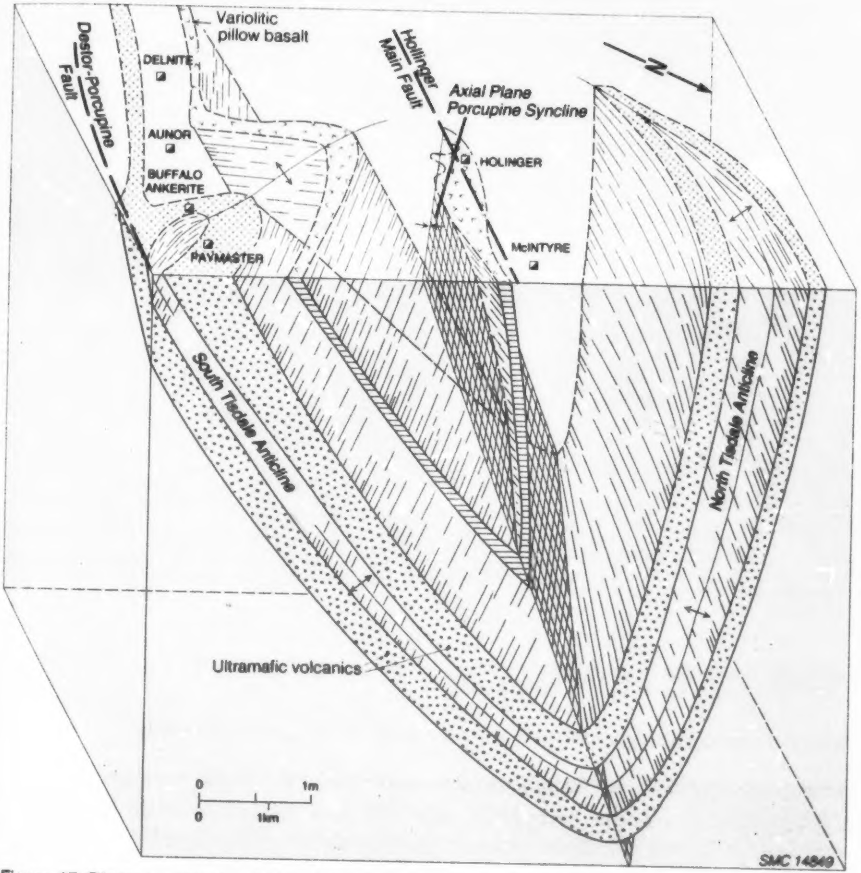

Variolitic pillow basalt
Destor-Porcupine Fault
DELNITE
AUNOR
BUFFALO ANKERITE
PAYMASTER
Hollinger Main Fault
Axial Plane Porcupine Syncline
HOLINGER
McINTYRE
N
South Tisdale Anticline
North Tisdale Anticline
Ultramafic volcanics
0
1m
0
1km
SMC 14849

Figure 17–Diagrammatic sketch showing interpretation of main part of the Timmins gold camp; illustrates the refolding of an anticlinal structure (now represented by the South and North Tisdale Anticlines) about the easterly trending Porcupine Syncline. For line of cross-section *see* Figure 15.

curs where fluviatile quartz-rich sedimentary rocks appear to conformably overlie the turbidite sequence. The actual contact is not exposed, but bedding on either side is conformable. Minor structures in the fluviatile sequence are the same as those in the underlying turbidite sequence, indicating that all the sedimentary rocks have undergone the same tectonism.

Figure 18a is a plot of the structural elements measured in the unconformity outcrop north of South Porcupine, Whitney Township; there is little variation in the cleavage and lineation orientations from those in Tisdale Township.

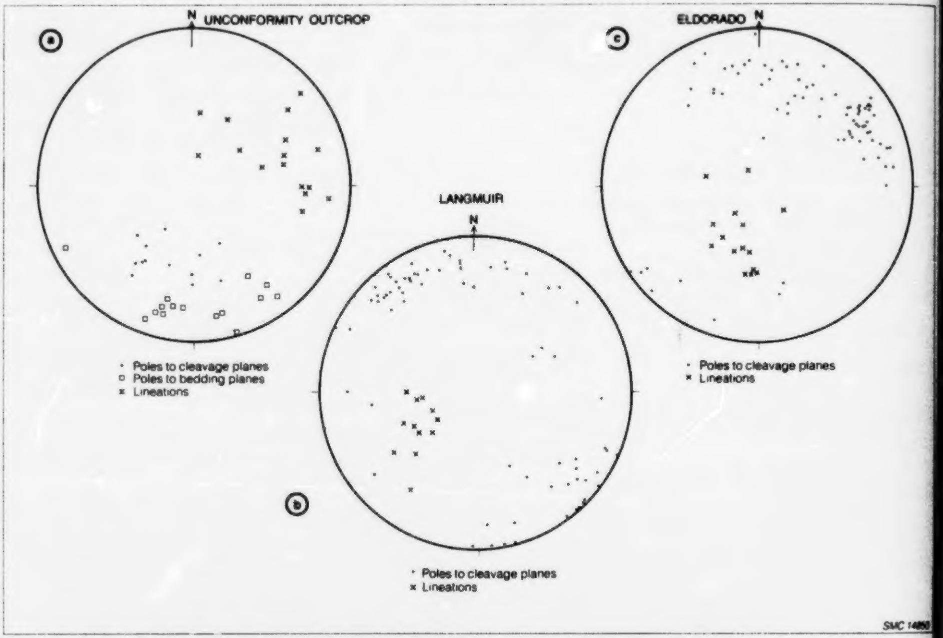

a
N
UNCONFORMITY OUTCROP
· Poles to cleavage planes
□ Poles to bedding planes
× Lineations
LANGMUIR
N
b
· Poles to cleavage planes
× Lineations
ELDORADO
N
c
· Poles to cleavage planes
× Lineations
SMC 1485

Figure 18a–Stereographic projection of structural elements in sedimentary rocks in unconformity outcrop 0.8 km north of South Porcupine.

Figure 18b–Stereographic projection of structural elements in south Langmuir Township.

Figure 18c–Stereographic projection of the structural elements in south Eldorado Township.

This suggests a similar strain pattern existed, and was related to the same folding episode which affected Tisdale Township.

FOLD STRUCTURE SOUTH OF THE DESTOR-PORCUPINE FAULT

South of the Destor-Porcupine Fault, the main structure is the Shaw Dome; the dome is elongated in a northwest-southeast direction and measures approximately 19 by 29 km. Intermittent layers of iron formation and a relatively continuous stratigraphic horizon of ultramafic volcanic rocks serve to outline the periphery of the dome which is the contact between the Deloro and Tisdale Groups. Layering at the margin of much of the dome dips steeply outward to near vertical. The dome is asymmetrical in that in the northeast portion, in

OGS 10 408

Photo 37–Relatively flat lying pillowed, vesicular calc-alkaline basalt. Northwest Shaw Township.

northwest Shaw and southwest Whitney Townships, the formations are relatively flat lying. Northward toward the Destor-Porcupine Fault the stratigraphy rapidly steepens to near vertical. The internal structure of the dome is imperfectly known because no marker horizon has been delineated. The main axis of the dome suggested by pillow facings is interpreted to be approximately east-west. The relatively flat-lying (Photo 37) strata in the northeast part of the dome is probably the result of cross-folding; the shallow plunging (approximately 20 to 25° northeast) Whitney anticlinal structure is superposed on the northeast part of the dome. The structure is particularly complex in this corner of the dome.

Linear elements, given mainly by mineral streaking, rodding, and lesser minor fold structures, plunge southwest in the southern part of the dome in Langmuir and Eldorado Townships. This is shown in Figures 18b and 18c; the foliations swing around the dome conforming to the stratigraphy whereas most of the linear structures retain a relatively constant southwest orientation. Very few structural measurements were taken elsewhere around the margin of the dome.

STRATIGRAPHY

A.G. Burrows (1911, 1912, 1915, 1924) initially subdivided the metavolcanics and metasediments into Keewatin and Timiskaming respectively. In the period 1929 to 1932, L.C. Graton *et al.* (1933) undertook a detailed study of the geology of the Hollinger Mine, and subdivided the volcanic rocks in the mine area into five series. On the basis of this data, further divisions and correlations of these stratigraphic units were made by B.S.W. Buffam (1948) and W.A. Jones (1948). These correlations were later revised and expanded on by Ginn (1960) and subsequently incorporated into the reports on Tisdale Township by Ferguson *et al.* (1968). M.E. Hurst (1939) was the first to subdivide the metasediments into Keewatin and Timiskaming.

On a more regional scale, W.R. Dunbar (1948) was the first to divide the volcanic rocks into two groups; the Deloro and Tisdale Groups. The Deloro Group was considered to be the older of the two groups and confined to the area south of the Destor-Porcupine Fault, particularly Deloro and Shaw Townships. The Tisdale Group was applied to the sequence of volcanic rocks hosting the main gold deposits in the area; this would include most of the volcanic rocks north of the Destor-Porcupine Fault. The sedimentary rocks were divided into two series; the Hoyle and Timiskaming. The Hoyle included not only the older sedimentary rocks, but also the acidic pyroclastic rocks (Krist fragmental) near the top of the volcanic sequence. The Timiskaming largely included the quartz-rich and conglomeratic sediments. The gabbroic and ultramafic rocks were classified as Haileyburian (post-Timiskaming), however, it was recognized they may be much older, namely pre-Tisdale Group in age.

N. Hogg (1950), further subdivided the metasediments, in that he included those metasediments south of the Destor-Porcupine Fault in Carman, Cody, and Whitney Townships as part of the Deloro Group.

Lorsong (1975), established the Porcupine Group to include all the clastic metasediments in the area. The Porcupine Group is divided into four formations, which from oldest to youngest are the Whitney, Beatty, Dome, and Three Nations Lake Formations. The Whitney Formation would in part include the Deloro Group sediments of Hogg (1950). The Three Nations Lake Formation incorporates most of what has previously been termed the Timiskaming (Dunbar 1948; Hogg 1950; Hurst 1939). The Beatty Formation includes most of what had previously been termed Keewatin sediments in Tisdale Township (Hurst 1939; Ferguson *et al.* 1968) and north Whitney Township (Hurst 1939). The Dome Formation has previously (Ferguson *et al.* 1968; Hurst 1939) been largely included as part of the Timiskaming. The author's interpretation of the distribution of stratigraphic units in the Timmins area is shown in Figure 19 and is enlarged upon in the following description.

Volcanic Rocks

In this report the two-fold subdivision of the volcanic rocks into the Deloro and Tisdale Groups is retained. In addition, each group is divided into three volcanic formations, which from older to younger are herein numbered I to III

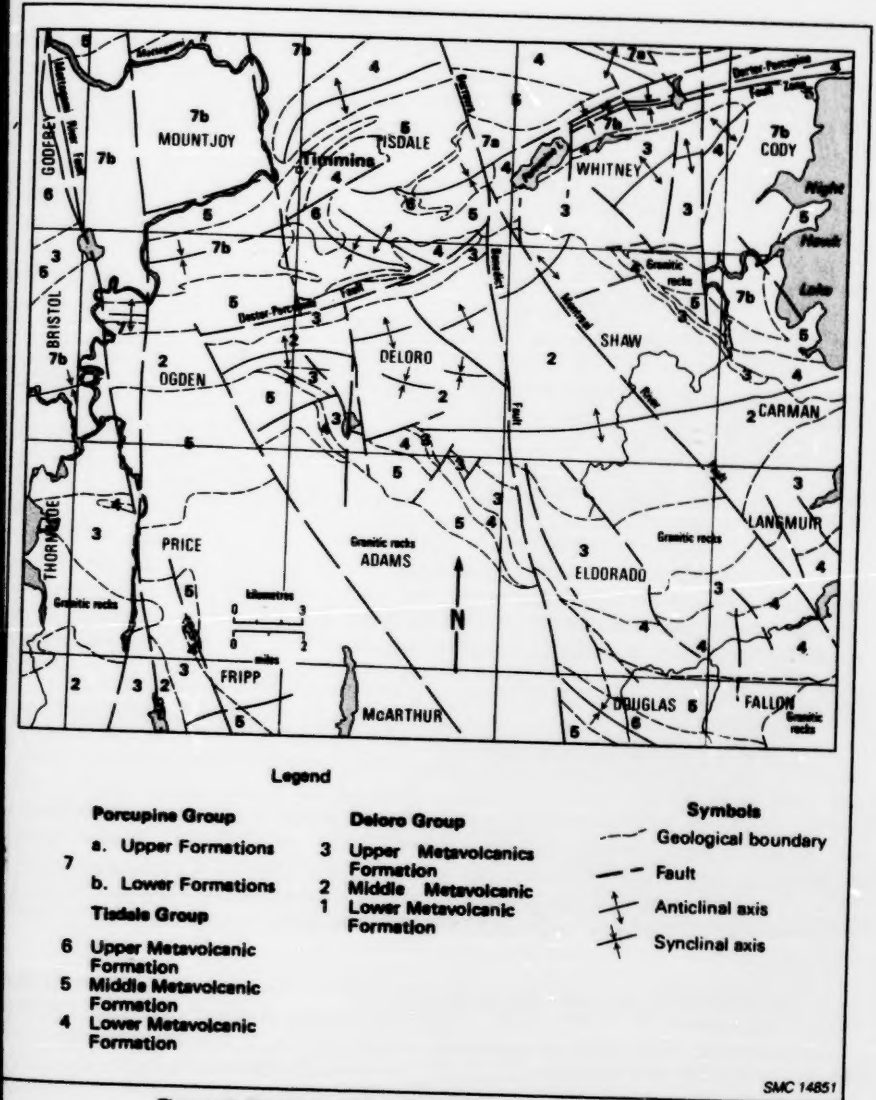

7b
MOUNTJOY
TISDALE
Timmins
7a
WHITNEY
7b
CODY
GODFREY
Mattagami River Fault
Destor-Porcupine Fault Zone
Night Hawk Lake
BRISTOL
7b
Granitic rocks
Benedict
Montreal River Fault
SHAW
2
OGDEN
DELORO
2
CARMAN
Fault
LANGMUIR
3
PRICE
Granitic rocks
ADAMS
3
ELDORADO
Granitic rocks
THORNLOE
Granitic rocks
kilometres
0
3
0
2
miles
N
FRIPP
McARTHUR
DOUGLAS
FALLON
Granitic rocks
Legend
Porcupine Group
7 a. Upper Formations
b. Lower Formations
Tisdale Group
6 Upper Metavolcanic Formation
5 Middle Metavolcanic Formation
4 Lower Metavolcanic Formation
Deloro Group
3 Upper Metavolcanics Formation
2 Middle Metavolcanic
1 Lower Metavolcanic Formation
Symbols
Geological boundary
Fault
Anticlinal axis
Synclinal axis
SMC 14851

Figure 19–Tentative distribution of stratigraphic units in the Timmins Area.

in the Deloro Group and IV to VI in the Tisdale Group.

It should be pointed out that both the Deloro and Tisdale Groups may in fact be supergroups when taken in the context of the entire Timmins-Kirkland Lake area (Pyke and Jensen 1976). In this case, the formations would necessarily be elevated to group status. For this report a group formation nomenclature is retained.

It has generally been assumed (Dunbar 1948, Hogg 1950, Carlson 1967), but never firmly established that the Deloro Group was older than the Tisdale Group: the two groups were by definition structurally and geographically separated by the Destor-Porcupine Fault. The age relationship (Hogg 1950) was inferred by: (1) the younger quartz-rich sedimentary rocks, commonly referred to as the Timiskaming Group (Ferguson *et al.* 1968) and which in this report form the upper part of the Porcupine Group (Three Nations Lake Formation), being associated with the Tisdale Group north of the Destor-Porcupine Fault; and (2) medium- to coarse-grained granitic intrusions being common in the Deloro Group and suggesting deeper erosional levels.

The recognition of ultramafic volcanic rocks north and south of the Destor-Porcupine Fault lead the author (Pyke 1974) to propose that these rocks were part of the same volcanic formation. If this is so, it would support the contention that the Deloro Group is older than the Tisdale Group; the former being largely confined to a domal structure, the latter to a synclinal structure. The ultramafic volcanic rocks on either side of the Destor-Porcupine Fault are probably correlative, this is suggested by; (1) such rocks are intercalated with similar volcanic flows (basaltic komatiites and Mg-tholeiites), and are overlain by a dominantly iron-rich tholeiitic basaltic sequence; and (2) the local juxtaposition of ultramafic volcanic rocks on either side of the Destor-Porcupine Fault, for instance south of the Aunor Mine.

Maximum thicknesses of the Deloro and Tisdale Groups are estimated to be about 5000 m and 7000 m respectively.

DELORO GROUP

I) Lower Volcanic Formation

This formation is proposed on the basis of the mapping carried out in the Peterlong Lake area (Pyke 1978a) which adjoins the southern boundary of the Timmins area. Here, minor ultramafic volcanic rocks, maximum thickness 300 m, are engulfed in a massive to weakly foliated diorite which forms the marginal phase of a large batholithic complex . It is only the northern extremity of these ultramafic rocks which extends into the southwest corner of the Timmins area. Nevertheless, the presence of ultramafic volcanic rocks at this stratigraphic level suggests that komatiitic rocks may have been more extensive and have underlain much of the Deloro Group in this part of the area. However, it is considered doubtful if ultramafic volcanic rocks underlie the Deloro Group in the Shaw Dome because none are exposed, even at the periphery of some of the intrusive rocks where one might expect the underlying formations to be faulted or domed up.

II) Middle Volcanic Formation

This formation forms the bulk of the Deloro Group and is best exposed in the central part of the Shaw Dome. The base of the formation is not exposed. The upper boundary, generally ill defined due to lack of outcrop, is placed at the base of the first recognizeable and persistant units of dacitic volcanic rocks, most of which are pyroclastic. Limited chemical analyses suggest that the felsic to intermediate volcanic rocks in the southern part of the Shaw Dome are possibly not as extensive as originally estimated (Pyke 1970, 1975a and b). Mafic volcanism may dominate to within a few hundred metres below the base of the main iron formation zone at the periphery of the dome. However, the contact is left as originally interpreted (Pyke 1970, 1975a and b) until more analyses become available. It is the top of the mafic volcanism which is taken as the upper limit of Formation II.

Formation II is composed almost entirely of flows of calc-alkaline basalt and andesite (Figure 20a) and it is only near the upper part of the formation that pyroclastic rocks dominate. Most of the intrusive ultramafic rocks are confined to this formation. The most continuous exposed section of Formation II is in northeast Deloro Township, where the maximum thickness is in the order of 3000 m.

III) Upper Volcanic Formation

This formation is characterized by the abundance of iron formation, both oxide and sulphide facies. Calc-alkalic rhyolitic and dacitic tuff and lapilli-tuff form the bulk of the formation. The felsic pyroclastic rocks are preferentially developed along the north and south sides of the Shaw Dome. In south Whitney Township, the maximum thickness is estimated to be about 1500 m. Near the southern margin of the dome, the thickness appears to be a maximum of approximately 2000-2500 m. Elsewhere as in Shaw, Carman, and southern Deloro Townships, the formation is largely delineated by a few tens of metres of iron formation and minor intercalated tuffs. Figure 20b is an Al_2O_3-(FeO + Fe_2O_3 + TiO_2)-MgO cation plot of volcanic rocks from the Deloro Formation III.

TISDALE GROUP

IV) Lower Volcanic Formation

Formation IV forms the base of the Tisdale Group and consists largely of peridotitic and basaltic komatiites at the base and interlayered komatiites and Mg-tholeiitic basalts in the upper part. The base of the formation is exposed near the northern boundary of Shaw Township. Here, serpentinized ultramafic flows conformably overlie sulphide facies iron formation. The contact is exposed in the eastern end of a trench in the iron formation near the southwestern

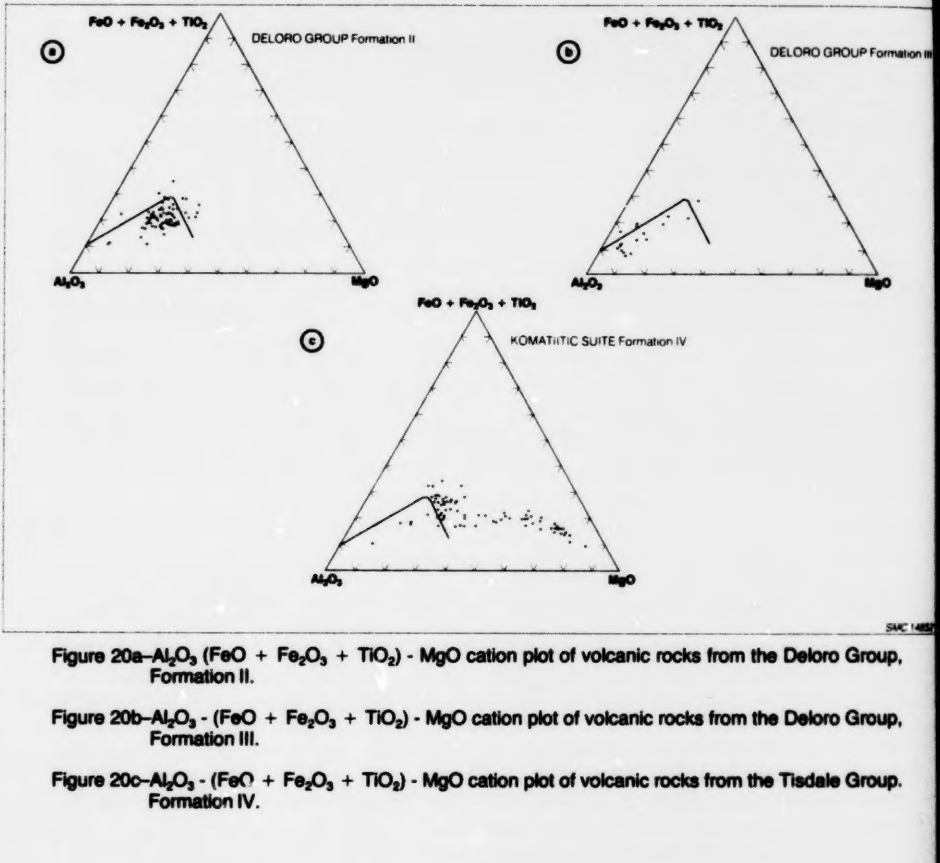


Figure 20a–Al_2O_3 ($FeO + Fe_2O_3 + TiO_2$) - MgO cation plot of volcanic rocks from the Deloro Group, Formation II.

Figure 20b–Al_2O_3 - ($FeO + Fe_2O_3 + TiO_2$) - MgO cation plot of volcanic rocks from the Deloro Group, Formation III.

Figure 20c–Al_2O_3 - ($FeO + Fe_2O_3 + TiO_2$) - MgO cation plot of volcanic rocks from the Tisdale Group. Formation IV.

corner of Goose Lake. Near Goose Lake, the formation only has a maximum thickness of approximately 300 m. Elsewhere around the dome, the exposure is so poor that it is difficult to obtain any reliable estimate of the thickness. Nevertheless, two of the thickest sections appear to be in north-central Carman and southern Langmuir Townships, where thicknesses may be as much as 3000 m respectively. There is still some doubt, however, about the stratigraphic positioning of the ultramafic flows near the southern boundary of Langmuir Township. Whether the flows represent part of the overlying formation, or a thickening of the komatiitic section in this part of the area is not known. It is suggested that the latter interpretation is correct and is incorporated in Figure 19.

North of the Destor-Porcupine Fault, the best exposed sections are in northern Tisdale and Whitney Townships. The maximum exposed thickness of Formation IV is 3000 m in northeast Whitney Township, the formation extends from the anticlinal axis north of the Hallnor Mine to the base of a massive Fe-tholeiitic basalt underlying the V8 variolitic basalt (Ferguson *et al.* 1968) in the southwest corner of Whitney Township. In the vicinity of the Pamour Mine, calc-alkalic basalt is intercalated with peridotitic komatiites. The calc-alkalic volcanic rocks may be an expression of the underlying Deloro Group; if so, iron formation is absent.

The author has included those rocks which plot in the Mg-tholeiite field on Figure 20c (see Figure 3b for field boundaries) as part of Formation IV (see Figure 19) because the most natural subdivision of the basal volcanic rocks of the Tisdale Group occurs at the first readily recognizable Fe-tholeiite. Furthermore, komatiitic flows have been demonstrated to display a complete differentiation sequence from ultramafic to basaltic compositions (for example, *see* Figure 11, Freds flow *in* Arndt 1975). Also in the Timmins area, differentiates of dunitic intrusions in the Shaw Dome show the same spectrum of compositions as is shown by the above komatiitic flows (*see* Figure 12c). However, in coding the geological map (back pocket) the nomenclature on tholeiitic volcanic rocks as shown in Figure 3b was followed, rather than incorporating the Mg-tholeiites as basaltic komatiites (which is depicted in Figure 3d). As pointed out previously, it is acknowledged that many or all of the Mg-tholeiites in the Timmins area may ultimately be shown to be products of fractional crystallization of a more mafic komatiitic source. For example, N.T. Arndt *et al.* (1977), and D.J. Whitford and N.T. Arndt (1977) demonstrated on the basis of rare earth elements (REE) that some of the low magnesium-bearing (approximately 7 percent Mg0) basaltic rocks in Munro Township were probably of komatiitic parentage.

The thickness of Formation IV varies considerably north of the Destor-Porcupine Fault from a maximum of 3000 m in northern Whitney Township to 2300 m in northwest Tisdale Township, to 1000 m near the Tisdale-Deloro Township boundary. In all three sections, peridotitic komatiites are confined to the lower part of the formation. Proportionately, the differing sections consist of approximately 20 to 25 percent komatiites, 65 percent Mg-tholeiitic basalt, and 15 percent Fe-tholeiitic basalt. Virtually all the Fe-tholeiitic basalt is toward the top of the formation and is intercalated with Mg-tholeiitic basalt. In addition, within the Fe-tholeiite field nearly all the compositions tend to Mg-enrichment rather than high iron compositions.

Figure 20c is a plot of the chemical composition of all analysed specimens from Formation IV.

V) Middle Volcanic Formation

Formation V is composed dominantly of iron-rich tholeiitic basalt (Figure 21a). North of the Destor-Porcupine Fault, the 99 flow (Ferguson *et al.* 1968, Graton *et al.* 1933) is taken as the base of the formation because it is the first easily recognized iron tholeiite in the lower part of the Tisdale Group. In many parts of the area, the 99 flow immediately underlies the distinctive V8 variolitic basalt (Ferguson *et al.* 1968, Chart L). This formation in a large part corresponds to the Vipond Subgroup of previous workers (Ferguson *et al.* 1968). The

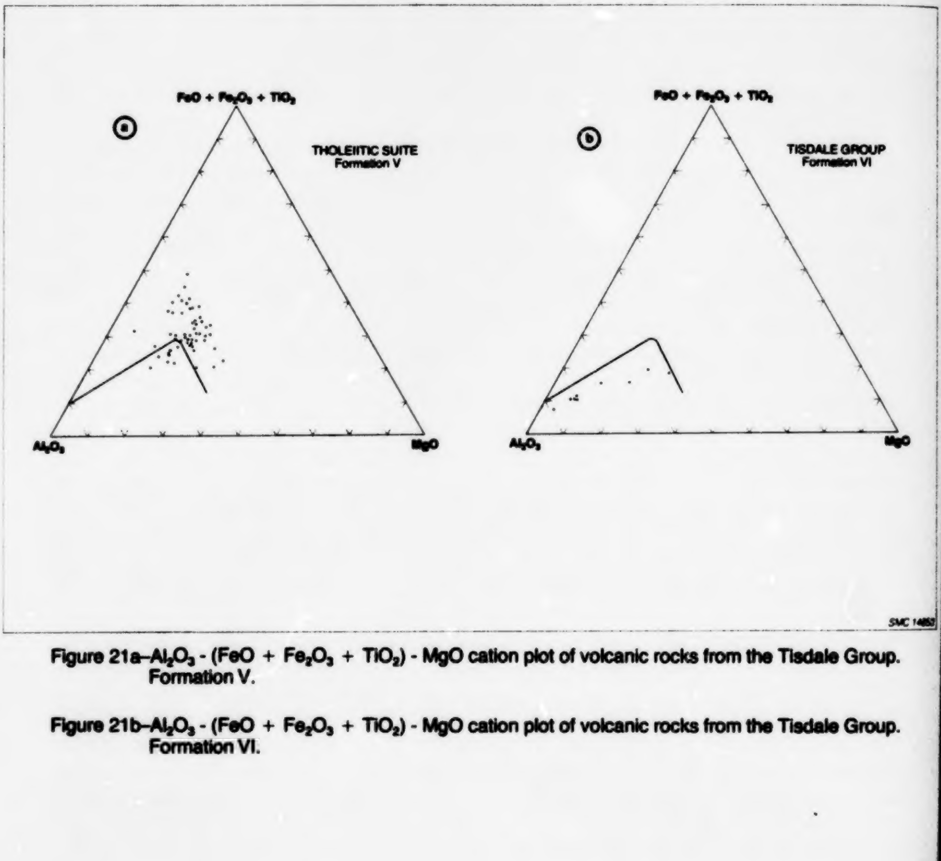


Figure 21a–Al_2O_3 - (FeO + Fe_2O_3 + TiO_2) - MgO cation plot of volcanic rocks from the Tisdale Group. Formation V.

Figure 21b–Al_2O_3 - (FeO + Fe_2O_3 + TiO_2) - MgO cation plot of volcanic rocks from the Tisdale Group. Formation VI.

maximum thickness of the formation varies from 300 to 1000 m, and the best exposed section is in south Tisdale Township in the area between the Dome and Paymaster Mines. Variolitic basalt forms a prominent part of the formation, notably the V8 and V10 flows (Ferguson *et al.* 1968). The top of the formation is marked by the abrupt termination of tholeiitic volcanism and the commencement of felsic, calc-alkalic volcanism.

South of the Destor-Porcupine Fault, the formation is not well defined because the exposure is extremely poor. Nevertheless, a few good isolated outcrop areas are available for examination confirming the presence of an iron-rich tholeiitic sequence overlying the komatiites. In contrast to the Fe-tholeiitic sequence north of the Destor-Porcupine Fault, variolitic basalt is virtually absent; only one occurrence was observed, and this outcrops approximately 1.5 km south of the map-area in Douglas Township.

VI) Upper Volcanic Formation

Formation VI is the uppermost volcanic formation and consists dominantly of felsic calc-alkaline pyroclastic rocks (Figure 21b). The formation is best developed in Tisdale Township where it has been referred to as the Krist fragmental (Ferguson *et al.* 1968), and has a maximum thickness of 350 m. Underlying the Krist fragmental and forming the base of the formation is a thin (zero to 100 m thick) black, poorly bedded carbonaceous unit of argillite that is known from diamond drilling and underground workings. Wacke interbeds are known to occur and are rare.

South of the Destor-Porcupine Fault, in Douglas Township, calc-alkalic crystal and lapilli-tuff ranging in composition from andesite to rhyolite and having a maximum exposed thickness of approximately 650 m form the uppermost volcanic sequence overlying the Fe-tholeiitic basalts. Rare intercalated ultramafic tuff (Figure 21b) and lean cherty sulphide iron formation are also present. The occurrence of ultramafic tuffs high in the stratigraphic sequence is not peculiar to this formation, because komatiitic tuffs are known to occur in the upper formations of the Porcupine Group.

Summary of Formational Chemistry

Figure 22a combines the chemical data for Formations II to V inclusive, and is representative of the three suites of volcanic rocks in the Timmins area; komatiitic, thoeliitic, and calc-alkalic.

Figure 22b outlines the boundaries of the bulk of the specimens within a given formation, and shows the compositional trends for the komatiitic, tholeiitic, and calc-alkalic suites. Of particular significance is the overlap in composition between the various volcanic suites; only a few rock samples from the area of overlap do not indicate the particular chemical affinity possessed by a rock.

Sedimentary Rocks

Sedimentation progressed continuously in parts of the area during the time that the volcanic rocks of the Tisdale Group were being formed. In Price, Thorneloe, and Fripp Townships, the lowermost metasediments are interlayered with metavolcanics of the Upper Formation (III) of the Deloro Group. Even though exposure is extremely poor in the Thorneloe-Bristol area (Ferguson 1962), volcanic rocks of the Tisdale Group appear to be absent, and the area was thus one continuous sedimentation, having commenced with the formation of the upper part of the Deloro Group. This sedimentation was largely contemporaneous with, and continued throughout the development of the Tisdale Group rocks to the east. Similarly, the author suggests that the metasediments in Mountjoy Township and northwest Tisdale Township may be largely equivalent to the Tisdale Group volcanic rocks, but again, exposure is poor and hence reliable stratigraphic data are lacking. In Whitney Township, the Whitney

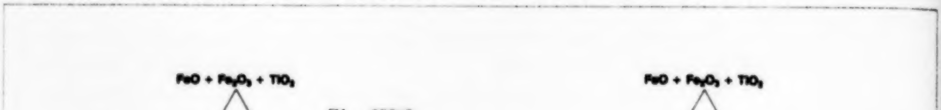


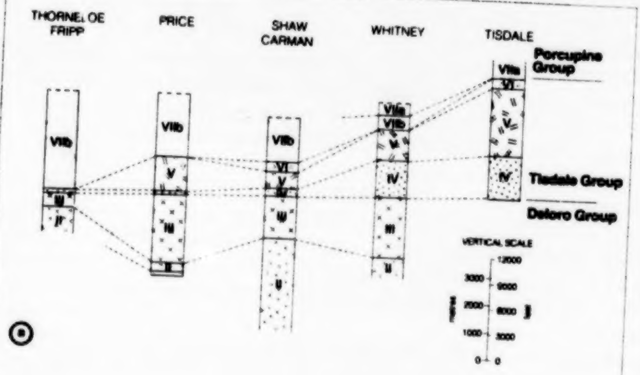
Figure 22a–Al$_2$O$_3$ - (FeO + Fe$_2$O$_3$ + TiO$_2$) - MgO cation plot of chemical analyses for Formations II to V inclusive.

Figure 22b–Al$_2$O$_3$ (FeO + Fe$_2$O$_3$ + TiO$_2$) - MgO cation diagram showing fields of calc-alkalic, tholeiitic and komatiitic suites as taken from Figure 22a.

Formation directly overlies the Deloro Group, and in Cody Township, the Whitney Formation is interlayered with the Basal Formation (IV) of the Tisdale Group.

The Dome and Beatty Formations in Tisdale and Whitney Townships are in part time equivalent to the volcanic rocks of the Tisdale Group. For example, the Dome Formation near the Dome Mine merges into and is intercalated with the pyroclastic breccia of Formation VI (Krist fragmental). Furthermore, this implies that the Beatty Formation which underlies the Dome Formation is at least in part equivalent to Formation V. Indeed, metasediments interpreted to be part of the Dome Formation in southeast Tisdale Township, east of the Preston Mine, are intercalated with the metavolcanics of Formation V.

Figure 23a shows a number of stratigraphic columns traversing the area in a general east-west arrangement, illustrating the time equivalence of sedimentation and volcanism. This is also diagrammatically depicted in Figure 23b.


THORNELOE
FRIPP
PRICE
SHAW
CARMAN
WHITNEY
TISDALE
Porcupine Group
VIIa
VIIb
VI
V
IV
III
II
Tisdale Group
Deloro Group
VERTICAL SCALE
12000
3000
9000
2000
6000
1000
3000
0
0
a

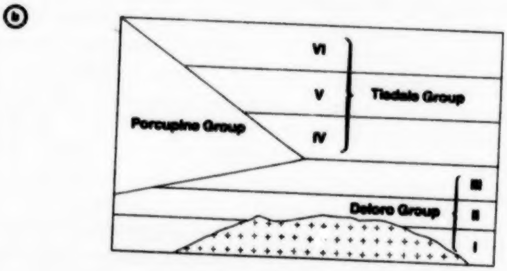

b
VI
V
IV
Tisdale Group
Porcupine Group
III
II
I
Deloro Group
SMC 14855

Figure 23a–Stratigraphic columns for the Timmins Area illustrating generalized correlations for the various stratigraphic units (numerals refer to same formations as in Figure 2).

Figure 23b–Diagrammatic illustration of time equivalence of sedimentation (Porcupine Group) and volcanism (Deloro and Tisdale groups) in the Timmins Area.

ECONOMIC GEOLOGY

Mineral production from the Timmins area has almost exclusively centred around the gold mines, where, within the confines of the map-area, a total of 31 mines, only three of which are currently in operation, produced a total of approximately 42 million ounces of Au and 8 million ounces of Ag to the end of 1973. If the entire gold camp is considered, this would include the northern parts of Tisdale and Whitney Townships not shown on Map 2455 in back pocket. The total production to the end of 1973 is 51 million ounces of gold and 12 million ounces of Ag. To 1980, the camp has produced 57 million ounces of gold, from some 37 mines, to rank Timmins as the largest gold mining camp in North America. Average grade of gold has been 0.254 ounce from the milling of 216 million tons of ore.

Minor scheelite (445 502 lbs) was produced intermittently from a number of gold mines between the period 1940-1953 (Ferguson *et al.* 1968).

Copper production began at the McIntyre Mine in 1953, and to the end of 1973 approximately 7 million tons of ore had been milled to yield 75 million pounds of copper.

Nickel production began at the Langmuir Deposit in 1973. Mining operations ceased in 1977, and to the end of 1976, 1.1 million tons of ore had been milled averaging approximately 1.5 percent nickel (Coad 1977).

During the period 1923 to 1926, 194 tons of asbestos were produced from the former Bowman Mine in central Deloro Township (Hewitt and Satterly 1953). In 1917 and in 1951, minor asbestos was produced from patented claim P6886 in the southeast part of Deloro Township (Carlson 1967).

Extensive magnesite deposits are known to occur near the south central boundary of Deloro Township and in southwestern Whitney Township. Neither have been exploited to date and the latter deposit may in addition contain commercial quantities of talc (Bowen, Middleton, and Fisher 1976).

The following discussion of the mineralization is not a comprehensive review, for such details, the reader is referred to specific references, rather, it is in part an attempt to integrate some of the mineralization into a meaningful framework with respect to structure and stratigraphy. Shortcomings, though apparent, may at the same time help in resolving the genesis of some of the deposits.

Gold

Since the discovery of gold in the Timmins area in 1909, a number of sources have been postulated for the mineralization; most theories (Carter 1948; Ferguson *et al.* 1968; Griffis 1962, 1972) have implied derivation of the gold from small stocks of quartz-feldspar porphyry, generally considered to be of subvolcanic origin (Griffis 1962, 1972; Graton *et al.* 1933). Other less popular theories have postulated lateral secretion of the vein material from the nearby volcanic rocks (Hurst 1935), or derivation from the large granitic batholiths (George 1967; Jones 1948), generally considered to be of Kenoran age.

In the ensuing discussion, it is the author's contention that the gold deposits are intimately related to the volcanism. The ultramafic volcanic rocks may have provided the main "source bed" for the mineralization, and the gold was subsequently mobilized, possibly in large part during carbonatization of the ultramafic rocks, and deposited in structurally favourable sites. The evidence for this is fourfold:

(1) A close spatial association exists between the ultramafic volcanic rocks and the gold deposits,

(2) The gold content of ultramafic volcanic rocks is high relative to other rocks,

(3) Recent analytical data (Keays 1975) suggest the gold is released from ultramafic rocks altered to talc-carbonate,

(4) Comparison with other Archean gold-bearing camps reveals many broad similarities.

The source-bed concept, whereby the mineralization is derived from the enclosing supracrustal rocks, is not new (Sullivan 1948), and has been invoked by R.W. Boyle (1961) to account for the gold deposits in the Yellowknife area. Boyle illustrated that the gold-bearing veins can be adequately explained by means of lateral secretion from the surrounding volcanic and sedimentary rocks during dynamothermal metamorphism.

R.P. Viljoen *et al.* (1969) recognized the importance of the high gold content of the ultramafic rocks in the Barberton area in South Africa. They considered that the komatiitic rocks were the principal transporters of gold from the mantle for the deposits found within the Steynsdorp Goldfields.

GOLD VEINS AND MINERALOGY

The gold deposits in the Timmins area nearly all occur in quartz veins which have a variety of shapes such as being continuous, tabular well defined veins, to the more common configuration of a complex network of parallel or branching stringers which follow a number of structures (Hurst 1935). Many are highly sinuous, contorted appearing, and display pinch and swell structures.

Graton *et al.* (1933) and M.E. Hurst (1935) have broadly classified the veins on the basis of structure (tabular, sinuous, branching, *en echelon*, boudinaged, etc.). In addition, very minor ore comes from irregular pyritized and sericitized zones in the basalts. The pyrite is auriferous, forms 5 to 15 percent of the rock, and occurs as disseminated cubes from 1.0 to 6.0 mm in size (Langford 1941).

Mineralogically, there are two main types of veins in the Timmins camp; quartz-ankerite and quartz-calcite veins. Most production has come from the quartz-ankerite vein system (Ferguson *et al.* 1968), and it is mainly these veins which are strongly associated with pyrite in the veins and in the adjoining wall rock. Quartz-calcite veins are most common outside the main gold-bearing zones, contain very little gold, and have little associated pyrite in the veins or wallrock. Other common accessories in the gold-bearing veins are sericite, tourmaline, albite, scheelite, galena, sphalerite, chalcopyrite, tellurides, and locally, fuchsite. Silver is alloyed with the gold, the average gold to silver ratio being approximately 5 to 1 (Ferguson *et al.* 1968).

Most of the gold-bearing veins are within the lower part of the Tisdale Group in the komatiitic and tholeiitic volcanic rocks, in particular from the Number 95 flow upward to the V10B variolitic basalt (Ferguson *et al.* 1968, p.59), which, in this report, would correspond to the lower part of the tholeiitic suite or Formation V. Less, but substantial ore occurs in veins in the ultramafic volcanic rocks, sedimentary rocks and porphyries. For details of the individual mines, the reader is referred to Ferguson *et al.* (1968).

ANALYTICAL DATA ON GOLD CONTENT OF ROCKS

At present, meaningful background gold analyses are not available for the rocks in the Timmins area. All the author's analyses have been done by fire assay and atomic absorption techniques for which 10 ppb is the lower limit of detection. Only a few scattered analyses have given values greater than this, and, therefore whether a regional geochemical anomaly is identifiable on the basis of original rock type, alteration, structural, or stratigraphic setting, awaits further work. Analyses by neutron activation techniques are planned and will hopefully shed some light on this. At present analytical geochemical data from the literature must suffice. Unfortunately, however, the distribution of gold in rocks is not well established, primarily because of the minute concentrations.

Data published by Y.G. Scherbakov and G.A. Perezhogin (1964) indicate that ultramafic rocks contain relatively high concentrations of gold in comparision to other rock types. These authors have shown that there is a decrease in the gold content from ultramafic and mafic rocks to felsic rocks, by a factor of about 2 to 3. They reported the average gold content in five chondrites as 160 ppb, one achondrite as 10 ppb, 27 ultramafic rocks as 9.4 ppb, 14 rhyolites and trachytes as 5.4 ppb, 33 granites as 3.5 ppb, and eight granodiorites as 4.0 ppb. Scherbakov and Perehogin attributed the high gold content of ultramafic rocks to the concept of electronegativity which the authors stated provided a quantitative expression for the relative importance of ionic and covalent bonding in silicates. Gold, which has a very high electronegativity, tends to be bound with compounds having a minimum amount of ionic bonding, as found in the neso- and inosilicates (olivine and pyroxenes), thereby accounting for the high gold content of ultramafic rocks. Tectosilicates (feldspars, quartz), on the other hand, have a maximum amount of ionic bonding. Scherbakov and Perezhogin also stated that the extrusive varieties of rocks tend to contain more gold than their intrusive equivalents.

Gottfried *et al.* (1972) and Keays (personal communication) are of the opinion that much of the gold in rocks is related to the sulphide fraction. However, the manner in which the gold is included, whether it be as inclusions in lattice defects, in solid solution, or some other form, is not known. D. Gottfried *et al.* (1972) also stated that mafic silicates and iron and titanium oxides tend to be higher in gold content than are salic minerals such as quartz and feldspar.

According to Scherbakov and Perezhogin (1964), A.N. Zavaritskii (1955) determined the correlation between gold content and iron, magnesium, copper, and vanadium for a number of rock types. By far the highest correlation coefficient was between Au and MgO. This would reflect the affinity of gold for neso- and inosilicates, as suggested by Shcherbakov and Perezhogin (1964).

K.K. Turkekian and K.H. Wedepohl (1961) reported the average gold content of the ultramafic rocks to be 6 ppb, whereas basaltic and granitic rocks contain 4 ppb.

E.A. Vincent and J.H. Crocket (1960) studied the distribution of gold in the Skaegaard intrusion and found that the gold content increased from the microdiabase and gabbro of the chilled zone to the olivine gabbro in the upper part of the section. The granophyre and other late differentiates contain lower concentrations of gold.

Gottfield *et al.* (1972) concluded that there is a general tendency for mafic volcanic rocks to be higher in gold content than felsic varieties. These samples, representative of numerous volcanic associations, gave the following averages: 269 basalts up to 2.5 ppb; 26 andesites, 3.0 ppb; 9 dacites to rhyolites, 0.88 ppb; 77 quartz latites to rhyolites, 0.7 ppb; 10 trachydacites to trachyte, 0.6 ppb.

Crocket (1974) in a comprehensive review of the geochemistry of gold noted two generalizations:

(1) In plutonic and volcanic rocks, the gold content generally decreases from mafic to felsic types,

(2) The range of gold values for most igneous rocks is from 0.5 to 5 ppb; however, some ultramafic rocks, particularly dunite and harzburgite commonly have somewhat higher values.

Yet, as pointed out by P.G. Sighinolfi and C. Gorgoni (1977), ultramafic rocks also show the greatest variability in Au content, which has been interpreted as reflecting an inhomogeneous mantle source (Vakrushev and Tsimbalist 1972). Table 4 gives the average gold values for igneous rocks as compiled by Crocket (1974).

C.R. Anhaeusser *et al.* (1975) determined the gold content in 16 samples of komatiites and related rocks from the Barberton area in South Africa. The samples yielded low values, averaging 1.0 to 1.5 ppb. Viljoen *et al.* (1969) had previously reported values for the komatiites ranging from 5 to 20 ppb. These results are questioned by Anhauesser *et al.* (1969) because the assays were not done by neutron activation, the fire assay method was used.

J.H. Crocket and Y. Teruta (1976) analyzed a number of samples for gold from two diamond-drill holes from the Mid Atlantic Ridge. Three samples of ultramafic rocks and gabbros averaged 16 ppb and ten to 12 samples of basalts averaged 3.1 ppb.

SPATIAL ASSOCIATION OF GOLD MINES AND ULTRAMAFIC VOLCANIC ROCKS (PERIDOTITIC KOMATIITES)

Many of the gold mines near the southern boundary of Tisdale Township are in close proximity to ultramafic metavolcanics, and in part some of the orebodies occur within carbonatized ultramafic metavolcanics. This would include the Buffalo Ankerite, Aunor, Delnite, Preston, Dome, and Paymaster Mines (Photos 38 and 39). The theory that some of the carbonatized rocks which contain ore zones are, in fact, altered ultramafic volcanic rocks is based on correla-

TABLE 4 AVERAGE GOLD VALUES FOR IGNEOUS ROCKS (FROM CROCKET 1974).

Rock type	Number of analyses	Weighted average, all analyses
Plutonic rocks		
Salic		
Granite	310	1.7
Granodiorite	380	3.0
Aplite (including dikes and veins of granite and greisen	23	4.2
Intermediate		
Diorite, quartz diorite, monzonite, quartz monozonite, tonalite	261	3.2
Mafic		
Gabbros (including gabbro-diorite)	580	4.8
Ultramafic		
Mainly dunite and peridotite	149	6.6
Volcanic and hypabyssal rocks		
Salic		
Mainly rhyolite (including rhyodacite, felsite, latite and obsidian)	188	1.5
Mafic and intermediate		
Mainly basalt, andesitic basalt, andesite (51) trachyandesite and trachyte (2)	696	3.6

tion of the carbonatized rocks (or in some cases talc-chlorite schists) shown in published sections (Buffam 1948b; Ferguson *et al.* 1968; Kinkel 1948; Taylor 1948) with known altered and carbonatized ultramafic volcanic rocks on surface (Pyke 1975a). Commonly, however, the ore zones are not found in the ultramafic rocks, but occur nearby in the more competent sedimentary rocks, basaltic komatiites, tholeiites, or porphyries.

To the author's knowledge, no ultramafic metavolcanics outcrop in close proximity to either the Hollinger or McIntyre Mines, two of the largest producers in the gold camp. However, ultramafic metavolcanics could underlie the mine properties at depth, as illustrated in Figure 17; minor folding and faulting may have transported the underlying ultramafics much closer to the surface than depicted in the figure. Indeed, some of the chlorite-talc schists occurring in the lower levels of the McIntyre Mine (Ferguson *et al.* 1968) may form part of the ultramafic volcanic sequence. Nevertheless, a large part of the McIntyre and Coniaurum ore bodies are in Formation V comprising the komatiitic suite.

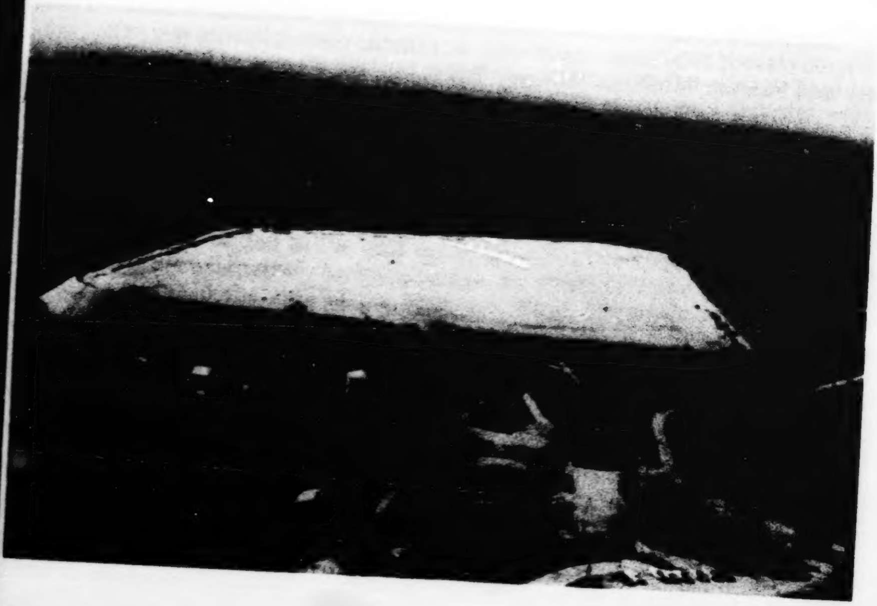


Photo 38–Aunor Mine and tailing pond, southeast Tisdale Township.

OGS 10 409

Photo 39–Paymaster Mill.

OGS 10 410

Elsewhere in the Timmins camp, other major gold producers can be shown to have close spatial association with ultramafic metavolcanics (e.g., the Hallnor and Pamour Mines in Whitney Township, see Figure 2, Figure 35, Chart C).

SOURCE OF THE GOLD MINERALIZATION AND THE ROLE OF CARBONATIZATION

Extremely low gold values are associated with felsic intrusive rocks (Gottfreid *et al.* 1972; Scherbakov and Perezhogin 1964). Also, there is no indication that gold is concentrated in late-stage differentiates (Gottfried *et al.* 1972). Therefore, it is considered very unlikely that the porphyries, or any associated quartz veins can be considered to be the source of the gold in the Timmins area, as has been suspected by some previous workers (Carter 1948; Griffis 1972; Smith 1948). Attention must be given elsewhere for the source of the gold, and the volcanic rocks, in particular, the ultramafic volcanic rocks, assume an important role as they tend to contain anomalously high gold values in relation to many other rock types. The probable importance of ultramafic rocks as regards gold mineralization has been recognized for many years, particularly by Russian geologists (Scherbakov and Perezhogin 1964), then more recently by Viljoen *et al.* (1969) and subsequently by others (Keays 1975; Imreh 1974; Pyke 1975b, 1976a).

Commonly, the ultramafic metavolcanics spatially associated with the gold mineralization in the Timmins area are largely carbonatized; talc-carbonate, talc-chlorite, and talc-carbonate-serpentine are common associations. Elsewhere, carbonatization is much less noticeable, and the ultramafic flows are largely altered to serpentine, tremolite, and chlorite. That carbonatization may be an important factor in the formation of Archean gold deposits was first hinted at by Viljoen *et al.* (1969). Their limited analyses suggested that gold may be leached from the komatiites during carbonatization. Keays (1975) determined the precious-metal content of the ultramafic host rocks from 14 nickel sulphide deposits in Western Australia. The analyses indicated that significant quantities of gold (3 to 4 ppb, Keays, personal communication) and sulphur were released during talc-carbonate alteration of the ultramafic rocks.

In the Timmins area, field relationships show that ultramafic rocks are much more susceptible to carbonatization than other rock types. Commonly, other volcanic or sedimentary rocks are at best only weakly carbonatized, although they are interlayered with ultramafic flows virtually completely altered to carbonate. The apparent susceptibility of ultramafic rocks to carbonatization, then becomes a very important factor, for during carbonatization, significant quantities of gold may be released (Keays 1975), which would then be available for secondary concentration. Keays (personal communication) suggests that it is the availability of gold in ultramafic rocks that makes them so important a source for gold mineralization. Even though other rock types may contain comparable or significantly greater tenors of gold than ultramafic rocks if there is no mechanism by which the gold can be made readily available for concentration, then the contribution of gold from these other rock types to any "deposit" may be negligible. As the ultramafic flows in the Timmins area are conspicuously altered to carbonate in the vicinity of the gold mines compared to non-productive areas, it appears that the alteration of the flows played an important role in the development of the gold deposits, especially because this alteration was almost certainly accompanied by a loss of gold (Keays 1975). In addition it is probably not solely the ultramafic volcanic rocks which contributed to the gold mineralization, but conceivably any rock that is carbonatized. In this regard, the entire komatiitic suite (Formation 4, Figure 19) as well as some of the tholeiites, sedimentary rocks, and porphyries could have contributed to the gold mineralization. For example, virtually all the basalts are extensively carbonatized in the upper part of Formation IV (komatiitic suite) in the area of the McIntyre Mine. Moreover, abundant silica would be released during carbonatization of the ultramafic or other rocks, providing not only a possible transporting agent for the gold, but much of the quartz in the associated veins and stockworks.

Conceivably, the porphyries may, in an indirect way, be related to the deposits by having provided either a heat source (Pyke 1975a and b) to assist in the remobilization of the gold from the ultramafics, or by having provided the CO_2 necessary to carbonatize the ultramafics. However, the exact nature of such a relationship is somewhat problematical, because as indicated by the work of Graton *et al.* (1933) and Hurst (1935), the porphyries antedate the development of the strong east-west schistosity in the area that accompanied the formation of the Porcupine Syncline. On the other hand, Graton *et al.* (1933) and Hurst (1935) considered that the auriferous quartz-carbonate veins have not been folded; rather these veins occupy dilatant zones formed during the folding of the rocks and the contemporaneous development of the regional schistosity. The author concurs with this, and is of the opinion that the dilatant zones for the deposition of the vein material formed during the second period of deformation; vein deposition and enlargement occurred throughout this period of deformation as described by Hurst (1935). It would therefore appear that the porphyries are not related to the deposits. Alternatively, it can be postulated that the CO_2-bearing solutions necessary to alter the ultramafic volcanics emanated up the Destor-Porcupine Fault zone and related fractures from some CO_2-rich source at depth.

Furthermore, shear folding in the vicinity of the gold camp is largely confined to the north side of the Destor-Porcupine Fault as previously discussed. This provides a possible explanation for fracturing and the development of depositional sites being largely confined to the north side of the fault zone.

COMPARISON WITH OTHER ARCHEAN GOLD CAMPS

Other important gold producing camps within Archean greenstone belts also contain an abundance of ultramafic volcanic rocks. Within the Abitibi Belt, this includes the Holtyre, Kirkland Lake - Larder Lake, and Val d'Or areas. Many smaller isolated gold deposits can also be demonstrated to be in an environment that produced ultramafic volcanism, for example, the Porcupine Peninsula Mine, Munro Croesus Mine, and Joburke Mine.

In the Holtyre area, V.K. Prest (1951) indicated the presence of numerous spinifex-bearing volcanic rocks which are most likely ultramafic volcanic rocks. Other ultramafic volcanic rocks in the same area have also recently been identified by Jensen (1975).

Ultramafic volcanic rocks are presently known to occur in the Kirkland Lake - Larder Lake area (Jensen 1975; Pyke 1975b). The Kerr Addison Mine, the largest producer in the Kirkland - Larder area, is intimately associated with ultramafic volcanic rocks, which to a large degree are highly carbonatized.

Ultramafic rocks form an important part of the stratigraphic succession in the Val d'Or area (Ministere des Richesses Naturelles du Quebec 1967). Many of the ultramafic rocks have recently been recognized as being of volcanic origin (Imreh 1974, and U.K. and D. Kretschmar 1974, personal communication).

It is not unlikely that some of the ultramafic and carbonatized rocks associated with the gold deposits (Ferguson 1962, 1965, 1966, 1968; Chisholm 1951) in the Red Lake area of northwestern Ontario are of volcanic origin (Ferguson 1975, personal communication).

Viljoen *et al.* (1969) presented a detailed study of the Steynsdorp Goldfield in the Barberton area of South Africa. They demonstrated excellent stratigraphic control for the gold mineralization; most is in proximity to a sedimentary unit (Middle Marker) of tuffaceous shale, carbonate, and chert. The sedimentary unit varies from a few to several hundred feet in thickness and caps the Komatii Formation, consisting largely of komatiites (komatiitic basalts and ultramafic flows). The komatiites yielded gold values ranging from 5 to 20 ppb, whereas the highest gold contents (average 75 ppb) were from the Middle Marker horizon. Viljoen *et al.* (1969) attributed the high gold content of the shales to their being derived from the underlying komatiitic rocks by sedimentary and biogenic processes. Further concentration of gold into economic deposits is attributed to dynamothermal metamorphism imposed by nearby granitic plutons on the Middle Marker horizon as well as the underlying komatiitic volcanic rocks.

In Western Australia, the Golden Mile of Kalgoorlie has recently been recognized to contain ultramafic volcanic rocks. Here, the Hannans Lake Serpentinite (Travis *et al.* 1971), which forms the basal formation of the Kalgoorlie succession, is considered to be of volcanic origin (G. Travis 1973, personal communication). Perhaps the general absence of ultramafic volcanic rocks may in some way assist in explaining why Archean greenstone belts are lacking economic gold deposits, although numerous "showings" are known.

SUMMARY AND CONCLUSIONS

Many of the gold deposits in the Timmins area can be demonstrated to be in close proximity to the ultramafic metavolcanics (*see* Figures 3a and 3d); some ore zones are within ultramafic metavolcanics. Available analytical data indicate that ultramafic volcanic rocks and probably associated komatiitic basalts are anomalously high in gold content compared to other rock types. Analyses also suggest that carbonatization of the ultramafic rocks may have led to leaching of the contained gold, the gold subsequently being deposited with quartz-carbonate in structurally favourable sites. This is strongly supported by field evidence, in that many of the ultramafic volcanic rocks near the gold mines are highly carbonatized. Furthermore, intensive structural deformation appears to have been a prerequisite for the development of the necessary dilatant zones for vein deposition in the Timmins area.

If the above relationship is valid, that the ultramafic volcanic rocks provided the principal source bed for the gold deposits, then the recognition and delineation of these volcanic rocks provides an extremely useful exploration tool. Related gold deposits might be expected to have a stratigraphically related spatial distribution. Prime exploration targets would include areas containing ultramafic volcanic rocks which display extensive carbonatization and strong structural deformation.

Conceivably, the recently recognized widespread and voluminous outpourings of ultramafic volcanic rocks during the Archean may have provided one of the major transporting agents of gold from the mantle during geological time. Carbonatization of the ultramafic volcanic rocks appears to have been an important factor in remobilizing some of this gold to form economic deposits. Perhaps, as suggested by R.P. Viljoen *et al.* (1970), some, or many of the detrital deposits of Proterozoic age were derived largely from preexisting Archean deposits related to ultramafic volcanic rocks.

Undoubtedly, the association of gold and ultramafic volcanic rocks is not applicable to all Archean gold deposits. Many other theories, notably that of R.H. Ridler (1970), who stressed the association of gold and exhalites, warrant considerable merit. However, if sufficient deposits do have a genetic relationship with ultramafic volcanism, which may be the case, then the recognition and delineation of ultramafic volcanic rocks could play an important role in the discovery of future gold deposits.

Nickel

Known nickel deposits in the area are largely confined to peridotitic komatiites at the periphery of the Shaw Dome in Langmuir and Eldorado Townships. Only the Langmuir Deposit, owned jointly by Noranda (51 percent) and Inco (42 percent) has proven to be economic. Of the remaining two deposits, the McWatters, contains approximately 600 000 tons grading 1.0 percent nickel; the Hart deposit contains only an erratic and discontinuous zone of nickel mineralization.

Perhaps the most important consideration of the nickel deposits just mentioned is that they all occur in peridotitic komatiites at or near the base of the Tisdale Group. Footwall rocks of the Deloro Group consist of felsic tuff and breccias, sulphide iron formation, calc-alkaline basalt-andesite, or serpentinite. Locally, there is some intercalation of the komatiites with the Deloro Group volcanic rocks. Where extremely detailed mapping has been done, it has been shown that some of the ore zones at the Langmuir Deposit are concentrated in the basal parts of flows filling footwall embayments corresponding to paleosurface features (Green 1978). Also, the basal komatiites are almost invariably the most Mg-rich flows. These rocks have been demonstrated to contain the most significant mineralization; not only at the Langmuir Mine, but in all deposits of this type (Naldrett and Arndt 1976).

Details for all the individual deposits are given in Pyke (1970, 1975a and b), T.L. Muir (1975), P.R. Coad (1977), and A. Green (1978). Only the Langmuir Deposit will be briefly described here.

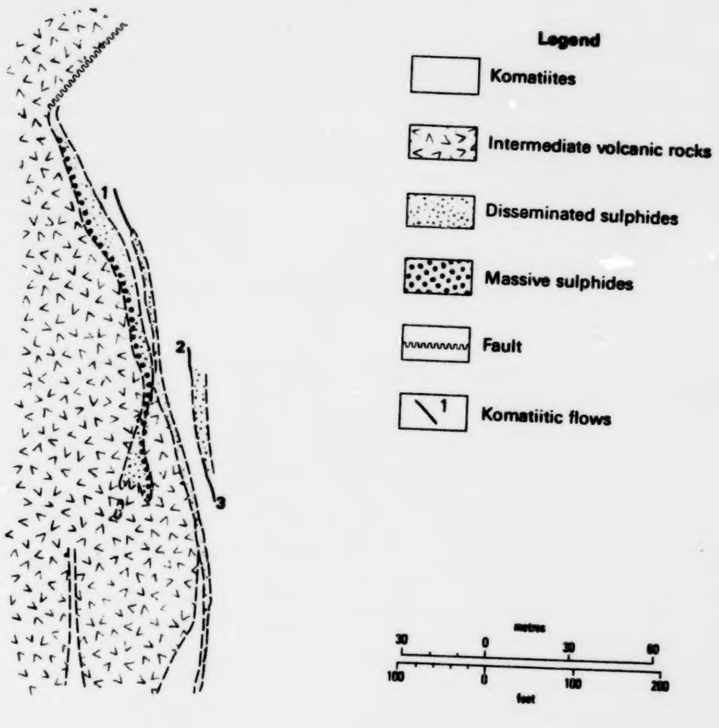
There has been extensive exploration along the contact between the Deloro and Tisdale Groups in Langmuir Township and to a lesser degree in Eldorado and Carman Townships. On the other hand, Adams, Ogden, Shaw, and Whitney Townships have received either only minor or virtually no exploration for nickel even though the same favourable lithostratigraphic contact is known to persist in these townships. Perhaps, the least explored area from this point of view is the contact zone between the Deloro and Tisdale Groups near the southern shore of Porcupine Lake in Whitney Township.

LANGMUIR DEPOSIT

The Langmuir Deposit consists of two ore zones (Number 1 and Number 2 zones); the Number 2 zone forms the main deposit and is along the east boundary of the area in Langmuir Township. In 1972 a shaft was sunk on the Number 2 zone, production commenced in 1973 and ceased in 1977. Total production to the end of 1975 was 549 979 tons grading approximately 1.5 percent nickel. Ore reserves as of June, 1976 (Number 2 zone) were 857 528 tons grading 1.75 percent nickel and 0.6 percent copper (Coad 1977).

Sulphide mineralization consists of pyrite, pentlandite, locally minor millerite, and minor chalcopyrite, generally located at or near the basal part of the lowermost komatiitic flows of the Tisdale Group; all the mineralization is within 30 m of the contact (Coad 1977). The orebody strikes northeast and dips approximately 80° southeast. The sulphides commonly occur as massive thin concordant lenses 0.3 to 2.5 m thick overlain by disseminated or net-textured mineralization 1.0 to 3.0 m thick. Minor ore also occurs interstitial to olivine blades in some spinifex-textured flow tops. Disseminated pyrite is common in the footwall volcanic rocks, and locally grades of 0.8 to 1.0 percent nickel are encountered (Coad 1977).

Spinifex texture and flow tops are in general poorly defined in the ore zone. Although there is no doubt that ultramafic flows are present, it cannot be ruled out that some of the massive ultramafic rocks may be contemporaneous high level sills (Green 1978). Certainly, the discriminant function of Muir (1975) classified many of the ultramafic rocks analysed from the mine as intrusive. One problem with the discriminant function classification, however, is that high MgO contents (greater than 38 to 40 percent) will tend to favour an intrusive origin, but A.J. Naldrett and N.T. Arndt (1976) have demonstrated that flows with these compositions host the majority of volcanic-type nickel sulphide deposits. Both the McWatters and Hart Deposits pose similar problems as to whether the mineralization is related mainly to flows or sills. Nevertheless, in all the deposits there can be little doubt that one is dealing with a surface or near surface volcanic environment.


Legend
Komatiites
Intermediate volcanic rocks
Disseminated sulphides
Massive sulphides
Fault
1 Komatiitic flows
1
2
3
metres
30
0
30
60
100
0
100
200
feet

SMC 14856

Figure 24–Langmuir Nickel Mine vertical cross section. Looking north at 7600N (modified after Green 1978).

Figures 24 and 25 are a section and plan view respectively through the Langmuir Deposit taken from A. Green (1978).

The Number 1 zone of the Langmuir Deposit is located approximately 1200 m southwest of the main mine. The ore zone is approximately 2 to 3 m thick consisting of a basal zone of massive pyrite - pyrrhotite - pentlandite, overlain by a disseminated sulphide zone. Here, the mineralization is at the base of a well-defined sequence of spinifex-textured peridotitic komatiites, which overlie a massive serpentinite (Muir 1975).

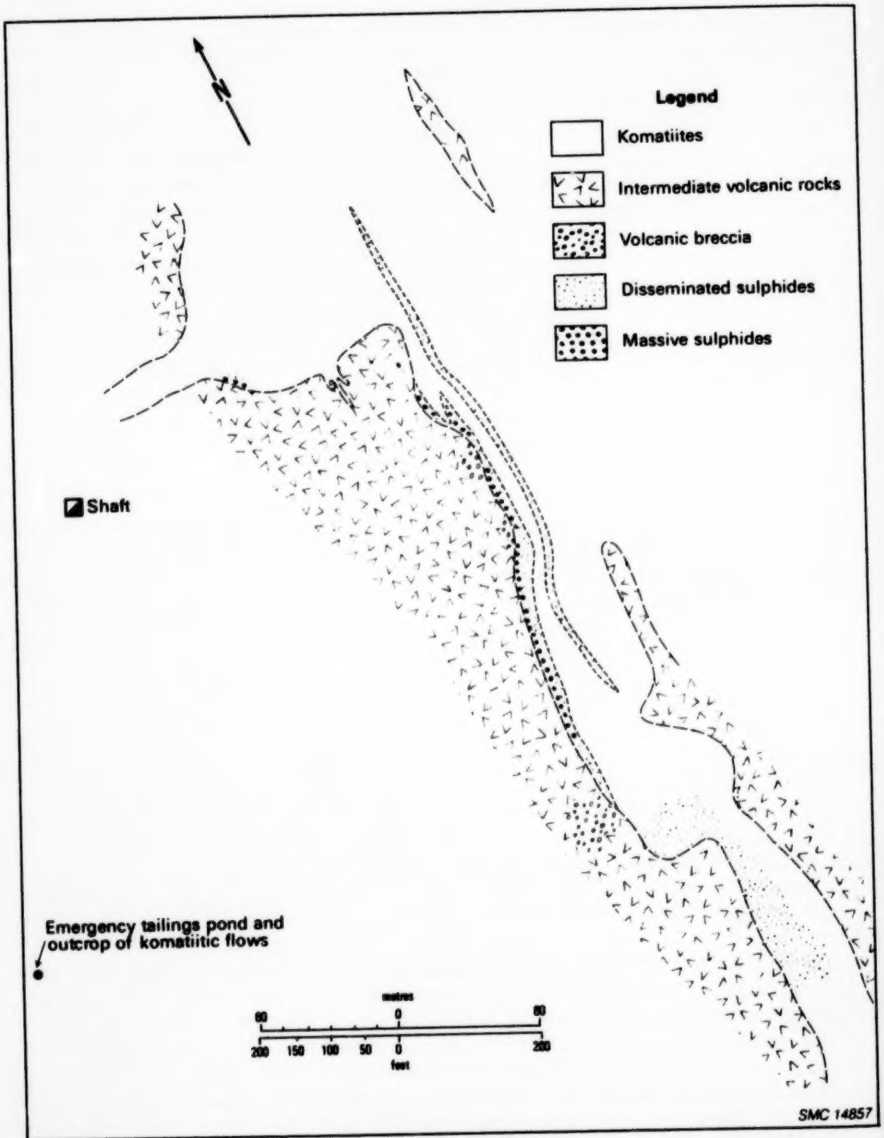

N
Legend
Komatiites
Intermediate volcanic rocks
Volcanic breccia
Disseminated sulphides
Massive sulphides
Shaft
Emergency tailings pond and outcrop of komatiitic flows
metres
60 0 60
200 150 100 50 0 200
feet
SMC 14857

Figure 25–Langmuir Mine Number 2 Zone Plan-view-Seventh Level (modified after Green 1978).

Magnesite

Two magnesite deposits are known in the area:

(1) Canadian Magnesite Mines Limited deposit near the south-central boundary of Deloro Township,

(2) Allerston deposit in the southwestern part of Whitney Township.

A third occurrence of magnesite, but of much more limited extent than the above two deposits, has been documented by Naldrett (1964) for west-central Eldorado Township.

The magnesite deposits occur in carbonatized parts of dunitic intrusions in the Shaw Dome. Talc is a common accessory, and in the Allerston property is of commercial importance.

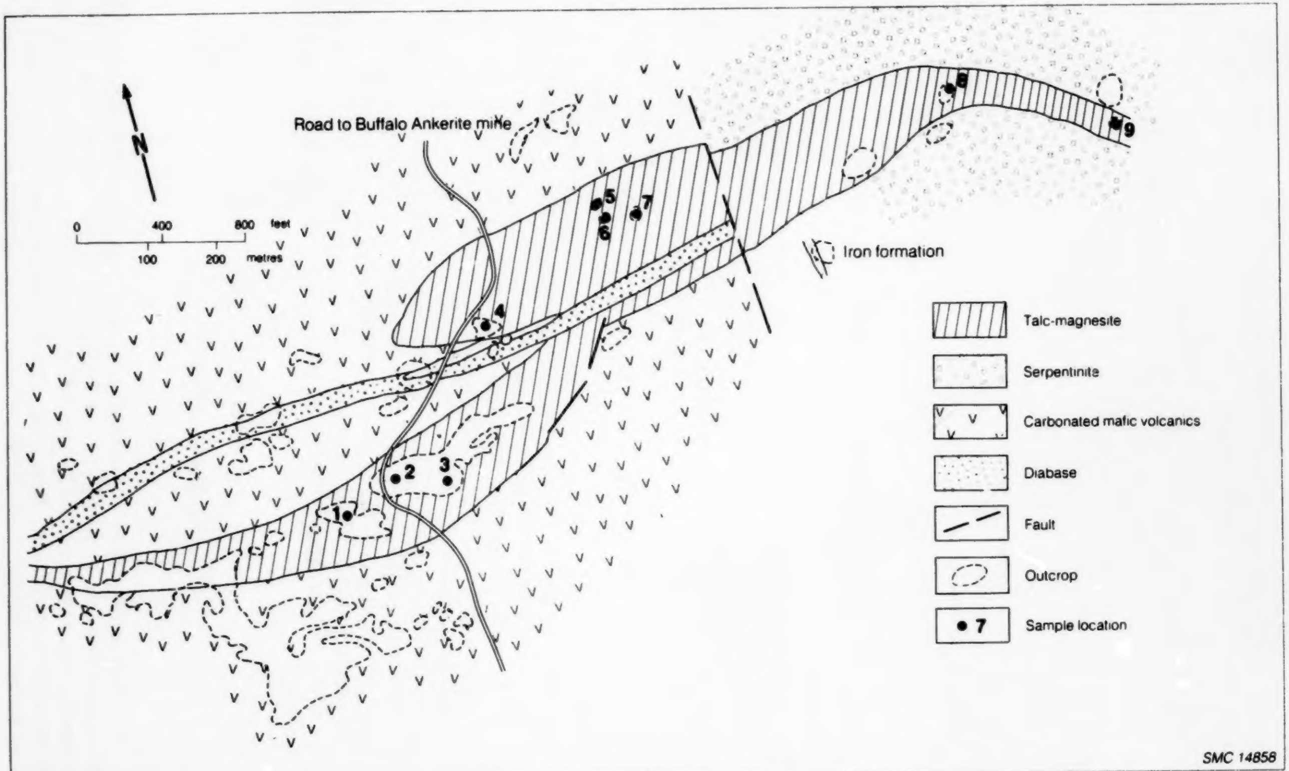
CANADIAN MAGNESITE PROPERTY

Figure 26 is a sketch map of the Canadian Magnesite talc-magnesite deposit (modified after Griffis 1972). The deposit is largely confined to two main outcrop areas, each being approximately 900 m in length and 120 m in width. Dips are steep and range from 60 to 70 degrees. The magnesite rock is typically massive, medium grained, white to light grey weathering and white on fresh surfaces; quartz veining is common. R. Griffis (1972) has distinguished four types of magnesite-bearing rock. The dominant type and what appears to form the bulk of the deposit contains approximately 54 ± 3 percent magnesite, 28 ± 3 percent talc, 16 ± 3 percent quartz and 3 percent iron oxides. Other types of magnesite-bearing rock are gradational into serpentinite and contain minor to 40 percent magnesite and variable amounts of talc, serpentine and quartz (Griffis 1972). Griffis reported one outcrop near the east end of the deposit which contains approximately 70 ± 4 percent magnesite, 16 ± 3 percent quartz, 8 ± 2 percent talc and 1 percent iron oxide. Table 5 gives the chemical analyses and calculated mineral content of nine samples reported by Griffis (1972).

R.D. Lawrence (1962) in an unpublished report suggested the deposit was of commercial importance. Subsequently Griffis (1972) indicated that Canadian Magnesite Mines Limited were at that time operating a pilot plant to assess the economic potential of the magnesia products. In 1977 the property still remained idle.

ALLERSTON PROPERTY

A talc-magnesite deposit (Photo 40) in southwestern Whitney Township was first discovered and staked by Ralph Allerston (Photo 41) in 1974. In 1975, the property was optioned by Rosario Mines Limited, who subsequently completed extensive trenching, sampling, detailed geological mapping, and geophysical surveys. In addition, 16 diamond-drill holes were sunk for a total of 930 m. The results of the exploration work by Rosario Mines Limited is con-


Road to Buffalo Ankerite mine
N
0
400
800
feet
100
200
metres
Iron formation
1
2
3
4
5
6
7
8
9
Talc-magnesite
Serpentinite
Carbonated mafic volcanics
Diabase
Fault
Outcrop
• 7
Sample location

SMC 14858

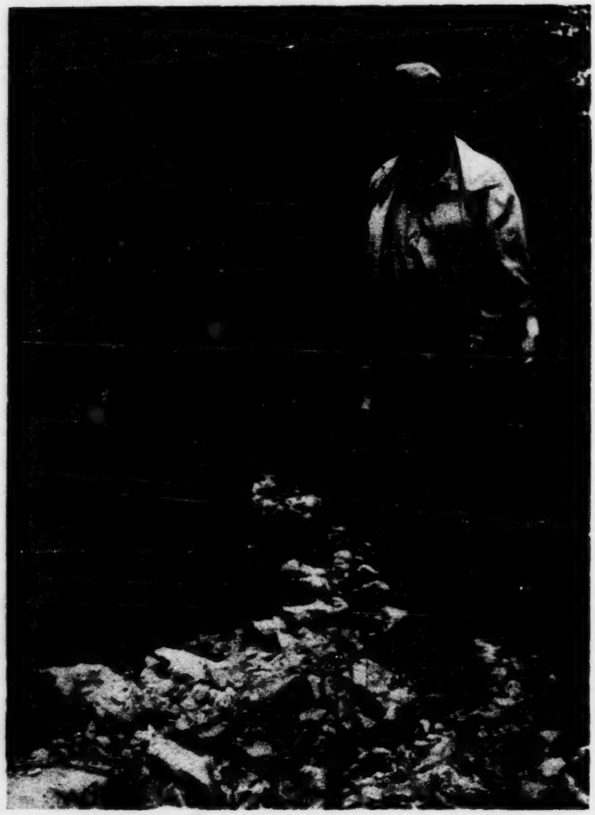
Figure 26–Geological sketch map of Canadian Magnesite Company Limited talc-magnesite deposit, south Deloro Township (modified after Griffis 1972).

TABLE 5 CHEMICAL ANALYSES OF BULK SAMPLES FROM PROPERTY OF CANADIAN MAGNESITE LIMITED, DELORO TOWNSHIP (FROM GRIFFIS 1972).

Sample Number	Soluble MgO	Total MgO	FeO	Fe_2O_3	CaO	SiO_2	Loss on Ignition (LOI)	Calculated Mineral Content		
								Magnesite	Talc	Quartz
1	27.8	32.6	1.8	3.2	0.07	24.2	32.7	61	16	15
2	26.4	....	...	...	Trace	....	28.8	48	...	...
3	26.3	31.0	1.0	4.9	Nil	22.7	31.2	55	15	13
4	28.8	32.6	3.3	1.9	0.09	25.2	33.7	60	12	18
5	26.9	30.4	4.8	0.8	0.10	28.2	32.7	56	11	21
6	24.4	29.4	4.9	1.0	0.98	25.9	32.0	60	16	16
7	27.8	34.1	2.8	3.0	0.08	24.1	34.8	61	20	12
8	34.2	35.9	4.1	1.2	0.08	18.0	39.7	72	6	14
9	20.8	23.4	3.1	2.4	0.07	25.0	25.8	44	...	...

OGS 10 411

Photo 40–Talc-magnesite rock on Allerston Property, rock is extremely soft and is easily cut by chain saw as is shown.



OGS 10412

Photo 41–Ralph Allerston at his talc-magnesite property in south Whitney Township.

tained in a voluminous unpublished report on the property by P. Bowen, R.S. Middleton, and Fisher (1977), and much of the following information is taken from that report.

Two zones (Figure 27) of talc-magnesite mineralization, a north and south zone, both approximately 30 m thick were outlined by Rosario Mines Limited. The talc-magnesite rock is massive to well foliated, medium grey, and has a talcose "feel". The north zone of mineralization is exposed on surface for an area of approximately 430 m by 300 m and contains an estimated 6 318 000 tons of talc-magnesite rock (Bowen, Middleton, and Fisher 1977). An additional

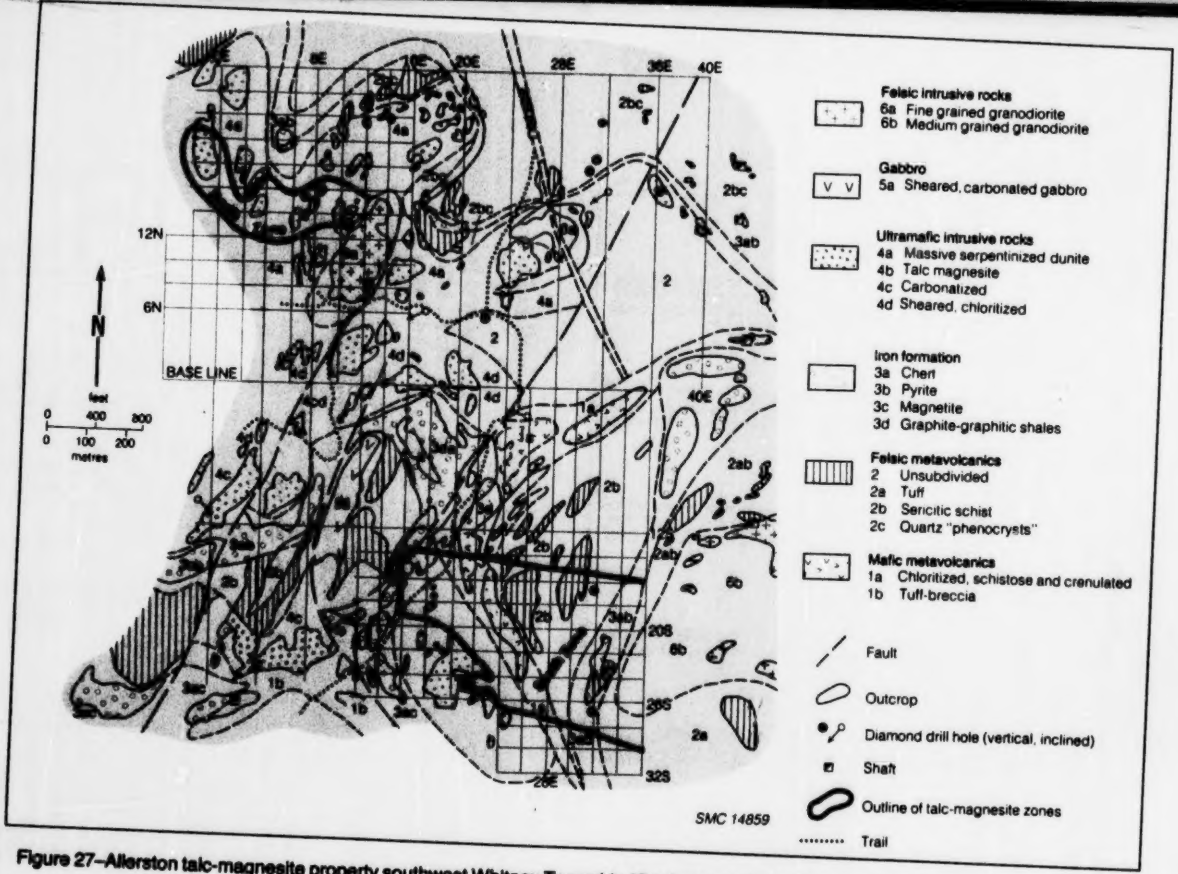

8E
16E
20E
28E
36E
40E
12N
6N
BASE LINE
N
feet
0
400
800
0
100
200
metres
20S
26S
32S
28E
SMC 14859
Felsic intrusive rocks
6a Fine grained granodiorite
6b Medium grained granodiorite
Gabbro
5a Sheared, carbonated gabbro
Ultramafic intrusive rocks
4a Massive serpentinized dunite
4b Talc magnesite
4c Carbonatized
4d Sheared, chloritized
Iron formation
3a Chert
3b Pyrite
3c Magnetite
3d Graphite-graphitic shales
Felsic metavolcanics
2 Unsubdivided
2a Tuff
2b Sericitic schist
2c Quartz "phenocrysts"
Mafic metavolcanics
1a Chloritized, schistose and crenulated
1b Tuff-breccia
Fault
Outcrop
Diamond drill hole (vertical, inclined)
Shaft
Outline of talc-magnesite zones
Trail

Figure 27–Allerston talc-magnesite property southwest Whitney Township (Geology modified after Bowen, Middleton, and Fisher 1976).

TABLE 6 CHEMICAL ANALYSES OF BULK SAMPLES FROM THE "NORTH ZONE OF THE ALLERSTON MAGNESITE PROPERTY, WHITNEY TOWNSHIP. (ANALYSES FROM BOWEN, MIDDLETON, AND FISHER 1976).

Sample Number	SiO_2	Al_2O_3	CaO	MgO	Fe_2O_3	CO_2	Assumed H_2O
354	31.9	0.7	0.76	34.3	7.83	21.4	3.11
355	31.7	1.0	0.45	34.3	6.60	23.1	2.85
356	31.5	1.3	0.95	32.5	7.58	20.5	5.67
357	30.5	1.1	0.49	34.3	6.72	21.8	5.09
358	34.6	1.2	0.42	34.6	6.33	18.4	4.45
359	34.8	2.4	0.87	31.7	10.50	12.4	7.33
360	34.8	0.7	0.43	33.3	9.14	18.7	2.93
361	34.5	1.8	1.28	32.2	8.82	16.3	5.10
362	30.8	1.2	0.28	33.9	9.64	20.1	4.08
363	36.8	1.9	1.55	31.5	8.63	14.8	4.82
364	35.3	3.6	0.34	30.9	12.30	12.9	4.66
365	31.3	0.9	0.24	33.3	10.30	15.4	8.56
366	36.3	2.5	0.27	32.9	8.11	14.2	5.72
367	31.2	1.2	0.29	33.1	9.54	19.7	5.07
368	35.6	1.8	0.40	32.5	8.12	15.9	5.68
369	36.2	1.9	0.64	31.6	7.33	14.1	6.23
370	32.9	1.4	0.34	33.5	8.51	18.6	4.75
371	25.7	1.2	0.32	34.9	10.20	23.7	3.98
372	30.8	1.1	0.43	35.7	7.30	21.7	2.97
373	35.3	0.8	0.30	34.4	8.58	18.1	2.52

TABLE 7 CHEMICAL ANALYSES OF BULK SAMPLES FROM THE "SOUTH ZONE" OF THE ALLERSTON MAGNESITE PROPERTY, WHITNEY TOWNSHIP. (ANALYSES FROM BOWEN, MIDDLETON, AND FISHER 1976).

Sample Number	SiO_2	Al_2O_3	CaO	MgO	Fe_2O_3	CO_2	H_2O
374	30.50	0.96	0.10	34.97	8.51	20.4	4.56
375	30.23	1.12	0.11	34.62	7.99	21.3	4.63
376	29.70	0.91	0.06	35.75	8.38	21.4	3.80
377	31.07	1.06	0.43	35.84	6.71	22.3	2.59
378	30.94	1.11	0.05	36.14	7.93	20.6	3.23
379	31.97	1.52	0.61	34.27	9.31	19.5	2.82
380	29.67	0.85	0.96	35.39	7.94	22.3	2.89
381	31.31	1.04	0.33	37.28	7.72	16.0	6.32
382	31.85	0.89	0.12	35.59	8.38	19.5	3.67
383	29.79	0.97	0.08	38.50	7.83	17.0	5.83
384	39.80	5.32	5.59	18.89	9.70	18.4	2.30

12 987 000 tons is estimated from geophysical work and limited trenching to underly a capping of peridotite approximately 30 m thick. Twenty bulk samples (Table 6) from the "North Zone" were submitted for analysis by Rosario Mines Limited and gave an average calculated composition of 33.3 percent magnesite, 1.9 percent dolomite, 46 percent talc, 7 percent chlorite, and 8.5 percent iron oxide.

The south zone contains two outcrop areas of approximately 60 000 and 20 000 square feet respectively. Total tonnage, largely based on five diamond-drill holes, is estimated by Rosario Mines Limited to be in the order of 31 590 000 tons of talc-magnesite rock. Ten bulk samples were analyzed (Table 7) from the "South Zone" and gave an average calculated composition of 37 percent magnesite, 1 percent dolomite, 50 percent talc, 6 percent chlorite, and 8 percent iron oxides.

The high iron content of the deposit has led to some concern about the feasibility of the magnesite being of commercial grade (R. Middleton, Rosario Mines Limited, personal communication, 1977) as indicated by current magnesite specifications. However, Rosario Mines Limited has not ruled out the possibility that the refractory properties of brick generated from the Allerston property may be a viable alternative for a number of furnaces (R. Middleton, personal communication , 1977).

Copper

Copper production has been confined to the McIntyre Mine in south-central Tisdale Township (Photo 42). Production commenced in 1963 and to the end of 1973, 6 852 000 tons of ore had been milled to yield 74 134 972 pounds of copper (Statistical files, Ontario Division of Mines). The most comprehensive description of the geology is given by Griffis (1962) who discovered the deposit in 1961. Other brief descriptions have been given by R. Griffis (1972) and D.R. Pyke and R.S. Middleton (1971).

The McIntyre copper deposit occurs in a leucocratic quartz-feldspar porphyry in south-central Tisdale Township. The porphyry is about 1500 m long, 460 m wide, and plunges 50°E, parallel to the penetrative lineation so pronounced in all the rocks in this part of the Timmins area. The porphyry is, in general, extensively sheared and sericitized, in addition to containing abundant gypsum, anhydrite, and locally hematite in and around the ore zones. A 120 m wide zone, characterized by extensive pyritization, contains disseminated chalcopyrite-bornite mineralization, and minor tetrahedrite, tennantite, molybdenite, and native silver are also present. It has been traced vertically for 1500 m (Griffis 1972). Ore grade material is confined to a number of shoots over half this vertical distance in a zone 360 m long and 90 m wide. The ore zone has the same plunge as the porphyry. Typically, the mineralization is concentrated along slip surfaces which plunge at the same angle as the porphyry. Less commonly, the sulphide minerals are finely disseminated in non-sheared massive sections of the porphyry. The concentration of the sulphides along slip surfaces suggests a redistribution of the mineralization occurred during shearing and hydrothermal alteration of the porphyry. That disseminated copper minerali-

OGS 10 413

Photo 42–McIntyre Mine, looking north across Pearl Lake.

zation is present in massive porphyry suggests that the sulphides are indigenous to the porphyry.

It is interesting to note that the ore zone, as delineated by the McIntyre Mine staff who use a cut off grade of 0.7 percent copper, consists of a number of ore shoots totalling about 8 million tons. However, the entire pyritized zone to at least a vertical depth of 1100 m contains copper mineralization. The copper values are not known in sufficient detail to give any estimate of an overall grade. However, the tonnage of this mineralized zone is 80 million tons or more (W. Fink, mine geologist, personal communication). The steep plunge of this particular ore zone would rule out any open pit operation, but some leaching process might be applicable to this or any similar deposit.

The presence of this copper deposit within the Pearl Lake porphyry is very important; it demonstrates that porphyry copper deposits formed during Early Precambrian times, and that additional deposits should be present.

REGIONAL GEOLOGY

Since 1972, the author has been involved in regional mapping in the Timmins-Kirkland Lake area, particularly in the area between Timmins and Matachewan. This has largely been confined to four quadrangles, bounded by Lon-

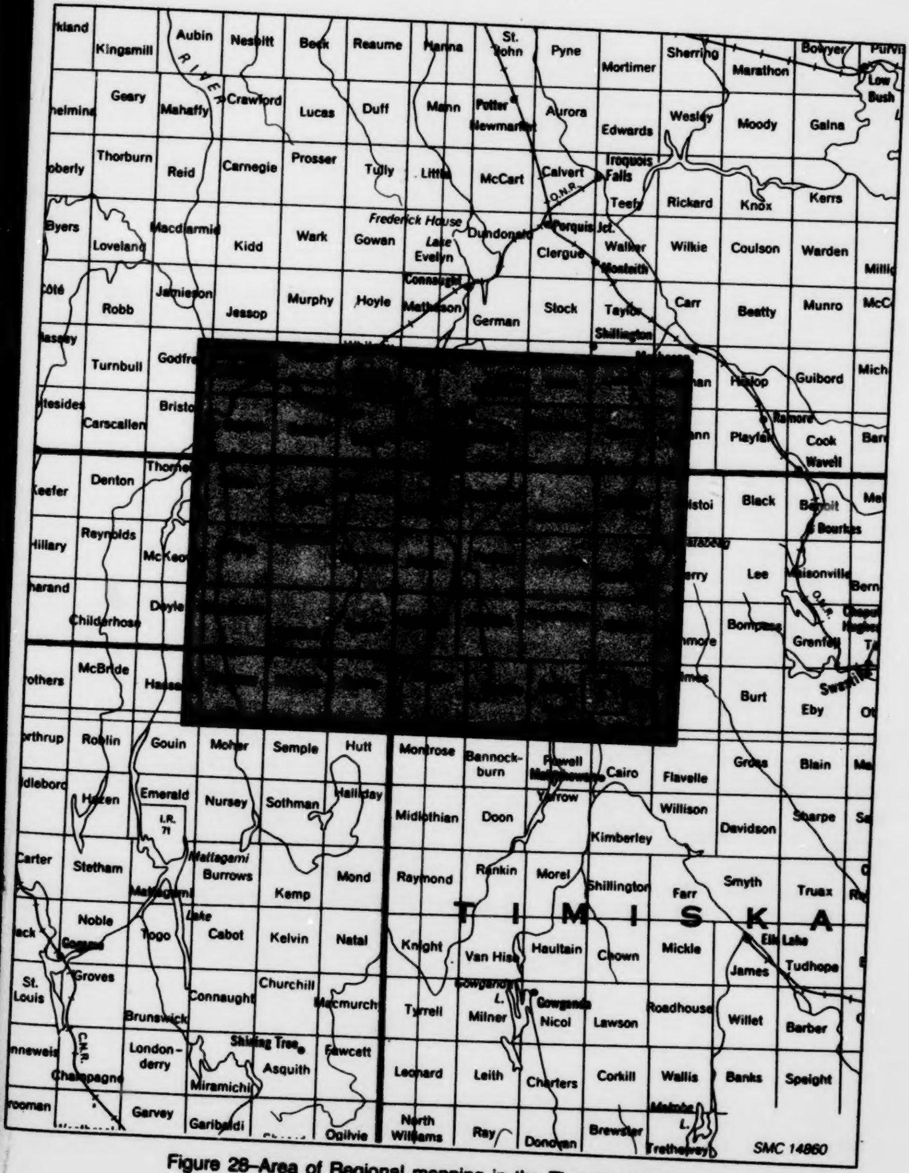

Kingsmill
Aubin
Nesbitt
Beck
Reaume
Hanna
St. John
Pyne
Mortimer
Sherring
Marathon
Bowyer
Low Bush
Geary
Mahaffy
Crawford
Lucas
Duff
Mann
Potter
Newmarket
Aurora
Edwards
Wesley
Moody
Calina
RIVER
Thorburn
Reid
Carnegie
Prosser
Tully
Little
McCart
Calvert
Iroquois Falls
O.N.R.
Teefy
Rickard
Knox
Kerrs
Byers
Loveland
Macdiarmid
Kidd
Wark
Gowan
Frederick House
Lake Evelyn
Dundonald
Porquis Jct.
Clergue
Walker
Wilkie
Coulson
Warden
Monteith
Jamieson
Connaught
Robb
Jessop
Murphy
Hoyle
Matheson
German
Stock
Taylor
Carr
Beatty
Munro
Shillington
Turnbull
Godfrey
Hislop
Guibord
Carscallen
Bristol
Ramore
Playfair
Cook
Wavell
Denton
Thorneloe
Black
Benoit
Bourkes
Reynolds
McKeown
Lee
Maisonville
Childerhose
Doyle
Bompas
Grenfell
O.N.R.
McBride
Hassard
Burt
Eby
Swastika
Roblin
Gouin
Mohr
Semple
Hutt
Montrose
Bannockburn
Powell
Matachewan
Cairo
Flavelle
Gross
Blain
Hazen
Emerald
I.R. 71
Nursey
Sothman
Halliday
Midlothian
Doon
Yarrow
Willison
Davidson
Sharpe
Kimberley
Carter
Stetham
Mattagami
Burrows
Kemp
Mond
Raymond
Rankin
Morel
Shillington
Farr
Smyth
Truax
Noble
Mattagami
Lake
Togo
Cabot
Kelvin
Natal
Knight
Van Hise
Haultain
Chown
Mickle
Elk Lake
James
Tudhope
T I M I S K A
Gogama
Groves
St. Louis
Connaught
Churchill
Macmurchy
Tyrrell
Gowganda L.
Milner
Gowganda
Nicol
Lawson
Roadhouse
Willet
Barber
C.N.R.
Brunswick
London-derry
Shining Tree
Asquith
Fawcett
Champagne
Miramichi
Leonard
Leith
Charters
Corkill
Wallis
Banks
Speight
Garvey
Garibaldi
Ogilvie
North Williams
Ray
Donovan
Brewster
Matabitchuan L.
Trethewey
SMC 14860

Figure 28–Area of Regional mapping in the Timmins-Matachewan area.

gitudes 80°30′ - 81°30′ West and Latitudes 48°00′ - 48°30′ North (Figure 28). The emphasis in this mapping has primarily been to outline the major lithostratigraphic units and regional structures. From this it was hoped that the integration of known metal deposits into a regional stratigraphic framework would assist in delineating new areas of mineral potential as well as additional targets in known mineralized camps. Certainly a better understanding of the stratigraphy has evolved; problems, however, still remain, and changes will be necessary as more data is accrued. Nevertheless, it was deemed practical to present a regional concept at this time.

When the region is viewed in a perspective larger than the Timmins area, it is seen that rocks defined as groups in the Timmins area are in reality supergroups, given that the correlations presented herein are correct. In turn, the formations would necessarily be raised to group status. This concept is incorporated in Figure 29, whereby the Deloro Group within the Shaw Dome is shown to be forming part of the Lower Supergroup in a regional context. The Tisdale Group, on the other hand, corresponds to the Upper Supergroup. This division of the volcanic rocks into two supergroups follows the subdivision previously presented by D.R. Pyke and L.S. Jensen (1976).

The division between the Lower and Upper Supergroups marks a major change in volcanism, and is the single most important stratigraphic marker in the area. Felsic, calc-alkaline, largely pyroclastic volcanism, with abundant associated iron formation forms the upper part of the Lower Supergroup. The base of the overlying Supergroup is dominated by komatiitic volcanism which is in large part ultramafic. Interlayering along the contact between the calc-alkalic and komatiitic volcanism is common, as is the intercalation of turbidites, marking the first major infiltration of sediments into the area.

The onset of komatiitic volcanism is taken to represent a common lithostratigraphic horizon throughout the area, as shown in Figure 29, and thus forms the basic underlying assumption on which much of the stratigraphic interpretation hinges. If this is incorrect, then changes are correspondingly required. For example, ultramafic volcanic rocks are known to occur at the base of the Deloro Group in the Peterlong Lake area (Pyke 1978a) and therefore can obviously occur at more than one stratigraphic level. Nevertheless, the particular komatiitic volcanic rocks shown to be correlative (Figure 29) provide a starting point for a stratigraphic framework which may ultimately aid in further interpretations.

Lower Supergroup

The Lower Supergroup is largely a calc-calkaline sequence; tholeiites are only known to be prominent toward the base of the supergroup in the Peterlong Lake area (Pyke 1978a and b). Iron formation is common at or near the top of the supergroup and forms a persistent stratigraphic marker throughout much of the area south of the Destor-Porcupine Fault. In fact, the abundance of iron formation is perhaps one of the most readily noticeable differences between the two supergroups; by comparison, iron formation is virtually absent from the Upper Supergroup. Furthermore, dunitic intrusions are also an entity confined

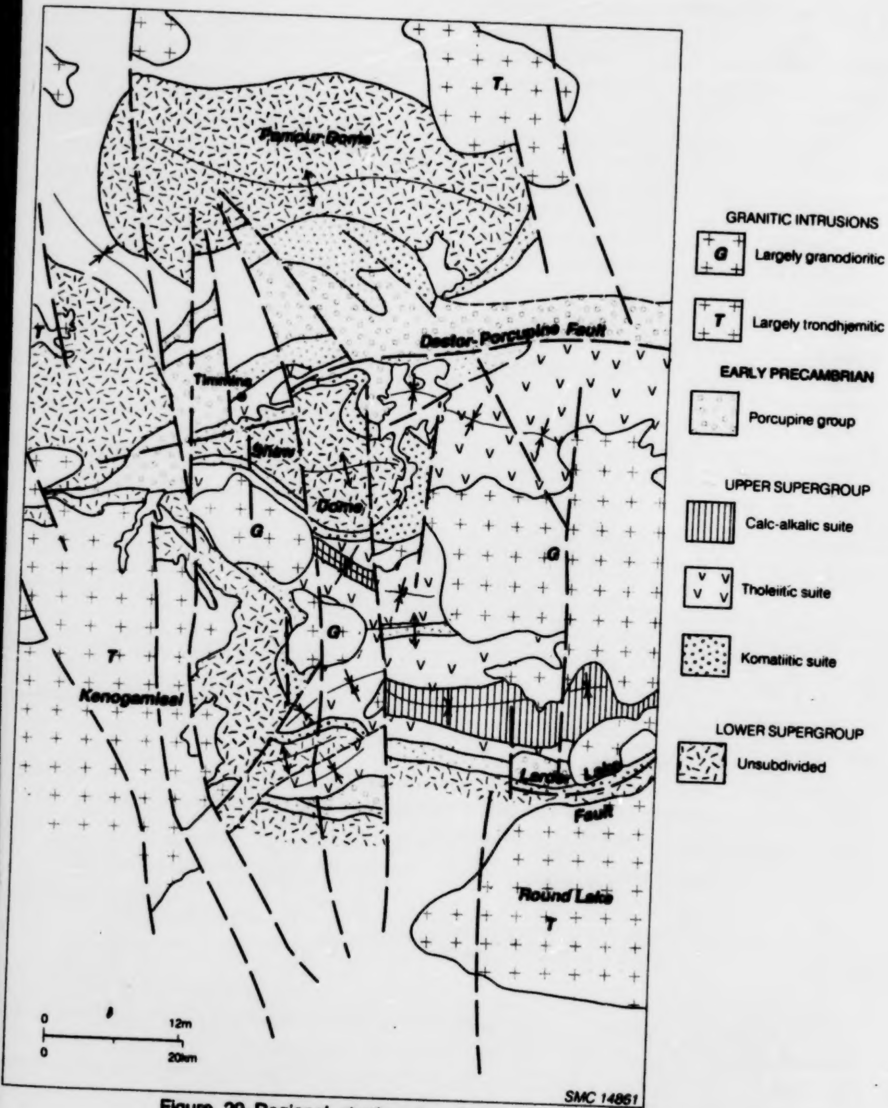

T
Pamour Dome
T
Destor-Porcupine Fault
Timmins
Shaw
Dome
G
G
G
T
Kenogamissi
Larder Lake
Fault
Round Lake
T
0
12m
0
20km
SMC 14861
GRANITIC INTRUSIONS
G
Largely granodioritic
T
Largely trondhjemitic
EARLY PRECAMBRIAN
Porcupine group
UPPER SUPERGROUP
Calc-alkalic suite
Tholeiitic suite
Komatiitic suite
LOWER SUPERGROUP
Unsubdivided

Figure 29–Regional stratigraphy of the Timmins-Matachewan area.

almost solely to the Lower Supergroup.

The Lower Supergroup is confined to domal-type structures such as the Shaw Dome and Pamour Dome (?), or to the margins of granitic plutons (e.g. Kenogamissi Batholith) which have pushed up (domed) the surrounding supracrustal rocks.

The interpretation of a domal structure north of Timmins (the Pamour Dome) is based largely on aeromagnetic data (GSC 1970) whereby a series of magnetic highs outline a somewhat oval shaped, east-west trending structure. Many of these "highs" are known from diamond drilling (Assessment Files Research Office, Ontario Geological Survey, Toronto) to correspond to ultramafic rocks, some of which are known to be flows, as shown by spinifex texture and flow contacts. A dome rather than a basin is inferred, in that the metasediments on the southern flank lie outside the structure and are assumed to be younger. The ultramafic flows at the periphery of the Pamour Dome are interpreted to form part of the komatiitic sequence at the base of the Upper Supergroup.

The Kamiskotia area northwest of Timmins is tentatively included in the Lower Supergroup for the following reasons:

> Firstly, ultramafic volcanic rocks are only known to occur near the top of the main volcanic sequence in the Kamiskotia area (R. Middleton, personal communication 1977).
>
> Secondly, no large gabbroic complexes like the Kamiskotia gabbro are known to occur in the Upper Supergroup, whereas layered gabbroic sills do intrude the Lower Supergroup, as for example in the Peterlong Lake area (Pyke 1978).
>
> The third, and perhaps most compelling reason is that the area is on the western margin of a trondhjemitic complex; similar batholiths to the south (Kenogamissi and Round Lake) are bordered by formations of the Lower Supergroup, and it is postulated that a similar situation exists in the Kamiskotia area.

The Pamour Dome and the Kamiskotia area could prove to be of a differing age than the supergroups proposed. The absence of exposure precludes any direct (physical?) correlation at this time.

Upper Supergroup

The Upper Supergroup is divided into three groups, each characterized by a distinct chemical composition; this subdivision is essentially an extension of the manner in which the Tisdale Group was divided in the Timmins area (see this report). The chemo-stratigraphic breakdown shown on Figure 29 is largely based on a number of unpublished analyses (Pyke, unpublished date).

The base of the Upper Supergroup is composed mainly of basaltic and peridotitic komatiites and magnesium-rich tholeiitic basalts. However, the komatiitic rocks are most common near the base of the Lower Group. This basal group is possibly correlative with the Stoughton-Roquemaure Group, largely a komatiitic sequence, described by Jensen (1978a). The overlying group is dominantly an iron-rich tholeiitic sequence and is interpreted to form the westward extremity of the Kenojevis Group (Dimroth *et al.* 1973, Jensen 1978a). The Upper Group is composed almost entirely of volcanic rocks of calc-alkaline chemical affinity, and is interpreted to be part of the Blake River Group of E. Dimroth *et al.* (1973) and L.S. Jensen (1975).

If the above correlations are correct, there is considerable thinning of the Upper Supergroup from east to west. The maximum thickness is approximately 30 000 m near the Ontario - Quebec provincial boundary (Jensen 1978), and approximately 12 000 m in the Timmins - Matachewan area.

Near the Ontario-Quebec boundary, the main structure within the Upper Supergroup is an easterly-plunging synclinorium (Irvine and Baragar 1968; Goodwin 1965; Jensen 1978). The Timmins-Matachewan area is interpreted to be located in the nose of this snyclinorium. Here, not only are the volcanic strata rapidly thinning, but they have been highly disrupted by batholithic intrusions. The emplacement of the Kenogamissi Batholith and the resultant updoming of the adjacent volcanic rocks of the Lower Supergroup marks the westward termination of the Upper Supergroup and associated synclinorium.

REGIONAL ECONOMIC CONSIDERATIONS

Once an interpretation of the regional stratigraphy is formulated, it is then practical to relate this to known mineral deposits in the area. In the author's opinion some of the more obvious generalizations are:

(1) Known Cu-Zn deposits are within the felsic calc-alkalic volcanic rocks at the top of the Lower Supergroup. The Kamiskotia deposits are a few hundred metres below the top of the Lower Supergroup; the Texas Gulf Deposit is at the interface of the two supergroups.

(2) South of the Destor-Porcupine Fault, iron formation seems to occupy the same stratigraphic position as the Cu-Zn deposits north of the fault.

(3) Nickel deposits are in the peridotitic komatiites at the base of the Upper Supergroup.

(4) Asbestos deposits are within the ultramafic intrusions, not the ultramafic flows. All the dunitic intrusions are within the Lower Supergroup.

(5) Magnesite and talc-magnesite deposits of commercial importance are confined to carbonatized dunitic intrusions and not ultramafic flows.

(6) Gold deposits are spatially and genetically related to the carbonatized parts of the komatiitic suite of volcanic rocks forming the lowermost group (formation?) of the Upper Supergroup. Furthermore, a strong structural control is evident as virtually all the deposits are close to the major east-west fault zones, the Destor-Porcupine and Larder Lake breaks. In Timmins all the deposits are: located within 6 km of the fault zone; a stratigraphic thickness of approximately 3000 m; and all but one of the many economic deposits is located north of the fault. In Matachewan both former producers are about 60 m north of the Larder Lake break. In the writer's opinion, further gold exploration is warranted in both the Timmins and the Matachewan camps because

virtually all the deposits were found from surfaces exposures, and the deposits appear to be in a large part stratigraphically controlled. Extensive areas of overburden in areas having a favourable stratigraphy may mask prime target areas. These occur in for example:

1) The area between the Aunor-Delnite Mines and the De Santis Mine and westward to the Mattagami River Fault.

2) A re-examination of some of the gold properties south of the Destor-Porcupine Fault is recommended. These occur expecially in or near zones of extensively carbonatized komatiites which occur in the following areas: a) The area of the former Balmoral Porcupine property in northern Adams Township, currently known to be overlying carbonatized ultramafic flows at the margin of the Shaw Dome.

(b) Carbonatized ultramafic flows in the vicinity of Goose Lake in north Shaw Township. This zone is also spatially associated with a large quartz-porphyry stock (Mt. Logano).

(c) The Tetrault property in McArthur Township (Pyke 1978b); again gold mineralization is related to carbonatized ultramafic flows and porphyry intrusions at the contact of the two supergroups.

As a general exploration, guide it appears that the contact of the two supergroups is of special significance. Certainly, the contact represents a dramatic change in volcanism, from felsic (calc-alkalic) to ultramafic (komatiitic). The nickel and gold deposits are related to the komatiites, whereas the Cu-Zn deposits are found within the underlying calc-alkaline sequence. Furthermore, many of the quartz- feldspar porphyries were emplaced along or near this general contact, and the porphyries have been postulated as sources for the gold, Cu-Zn, and Cu mineralization. Indeed, regardless of one's bias as to the origin of much of the sulphide and precious metal mineralization in the Timmins-Matachewan area, one cannot avoid the observation that a significant proportion of the producing mines, past producing mines, and significant prospects are spatially related to the contact of the two supergroups. This would encompass a general stratigraphic thickness in the order of 900 to 1800 m. In the author's opinion, it is this general contact zone which warrants the most rigorous exploration. In conjunction with this stratigraphic zone, the superposition of one or more of three additional elements, all referred to previously in this report, would appear to warrant special consideration. These elements are;

(1) Major fault or shear zones; for example, the Destor-Porcupine Fault in the Timmins Camp, the Larder Lake break at Matachewan, and the Burrows Benedict Fault (?) at the Kidd Creek Mine,

(2) Quartz-feldspar porphyries as in the Timmins gold camp, Kamiskotia area Cu-Zn deposits, and near the Kidd Creek (porphyry in southwest Prosser Township) deposit. Some porphyry is also known to be present in underground workings at Kidd Creek (R. Walker, personal communication, 1974),

(3) Extensive alteration in the form of carbonatization, sericitization, and chloritization.

TENTATIVE GENETIC SYNTHESIS

The distribution of the two Supergroups as interpreted, provides a basis for developing possible genetic models of the volcanic-plutonic pattern illustrated in Figure 29. Such a model is perhaps more meaningful when discussed within the framework of the entire Timmins-Kirkland Lake area, as depicted in Figure 30a. Briefly, it can be seen that the Lower Supergroup rocks are exposed either at the margins of the trondhjemitic batholiths (Kenogamissi, Round Lake, Lake Abitibi Batholiths) or in domal structures (Shaw and Pamour Domes). The Upper Supergroup is largely confined to a major synclinorium north of Kirkland Lake (Jensen 1978b), which is complexly bifurcated in the eastern part of the Timmins-Matachewan area, and is terminated near the east margin of the Kenogamissi Batholith (*see* Figure 29). The Upper Supergroup is 30 000 m thick near the Ontario-Quebec boundary (Nunes and Jensen 1980) and approximately 10 000 m thick (Pyke 1978a) in the area south of Timmins (Figures 30a,b, and c). The Porcupine Group is of sedimentary derivation and is time equivalent to the upper part of the Lower Supergroup and the entire Upper Supergroup of volcanic rocks. The batholiths display intrusive contacts with the Lower Supergroup volcanic rocks and are interpreted to have been largely emplaced after the formation of the Upper Supergroup because the Kenogamissi Batholith has tectonically deflected the nose area or the western extremity of the Upper Supergroup. Nevertheless, perhaps epizonal parts of these batholiths, namely the Kenogamissi and Round Lake Batholiths, were being deroofed at the time of formation of the Upper Supergroup, thus providing some of the detritus for the quartz-rich beds in the lower-most turbidites. The Shaw Dome may also be underlain by granitic rocks because a negative Bouger anomaly coincides with the dome (Middleton 1976), and a small stock of trondhjemite intrudes the southeast corner of the dome. The Pamour Dome on the other hand has a high Bouger anomaly (Middleton 1976) and has been interpreted by Middleton to be underlain by a gabbroic complex similar to the situation at Kam Kotia (Middleton 1973, 1975).

One of the main enigmas in the interpretation of this and many other Archean Greenstone Belts, is the origin of the large batholithic complexes peripheral to or enclosed within the greenstone belts. Examples of these are depicted in Figure 29, namely the Kenogamissi and Round Lake Batholiths. Very little data is available about these batholiths, in particular, the Kenogamissi Batholith. However, cursory examinations suggest that they are largely composed of well foliated to gneissic trondhjemite with a lesser, yet substantial amount of massive to weakly foliated sodic granodiorite. The granodiorite is commonly porphyritic and is intrusive into the trondhjemite.

Basically, there appears to be two divergent theories regarding the origin of similar batholithic complexes. These are:

(1) The batholiths largely represent original sialic crust upon which the volcanics were erupted. Subsequently, the granitic material was remobilized and intruded into the overlying volcanic rocks (Baragar and McGlynn 1976; Gorman *et al.* 1977).

(2) The less popular hypothesis that the granitic material represents partly melted or reworked supracrustal rocks, as proposed in various models by J.E. Gill (1961), A.Y. Glikson (1971, 1972) C.R. Annhaeusser

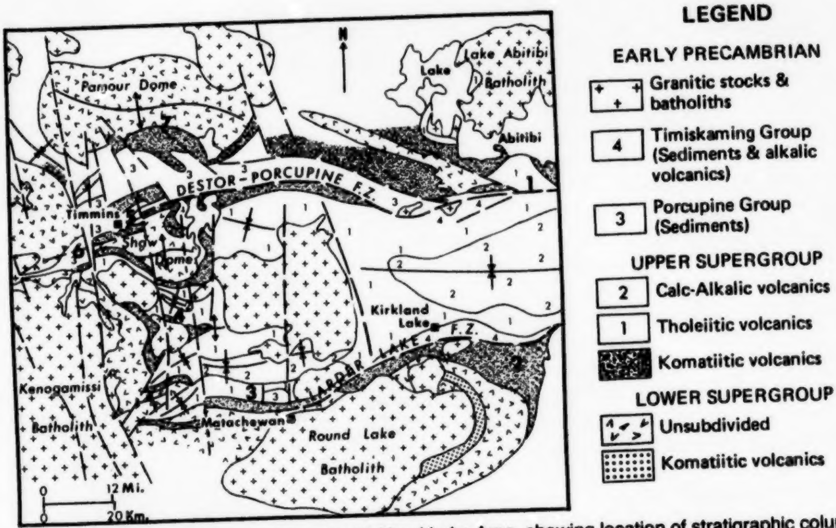

LEGEND
EARLY PRECAMBRIAN
Granitic stocks & batholiths
4 Timiskaming Group (Sediments & alkalic volcanics)
3 Porcupine Group (Sediments)
UPPER SUPERGROUP
2 Calc-Alkalic volcanics
1 Tholeiitic volcanics
Komatiitic volcanics
LOWER SUPERGROUP
Unsubdivided
Komatiitic volcanics
N
Pamour Dome
Lake Abitibi
Batholith
Abitibi
DESTOR-PORCUPINE F.Z.
Timmins
Shaw Dome
Kirkland Lake
LARDER LAKE F.Z.
Kenogamissi Batholith
Matachewan
Round Lake Batholith
12 Mi.
20 Km.

Figure 30a–Stratigraphy of the Timmins-Kirkland Lake Area, showing location of stratigraphic columns shown in Figure 30c. Geology by Pyke (1978) and Jensen (1979).

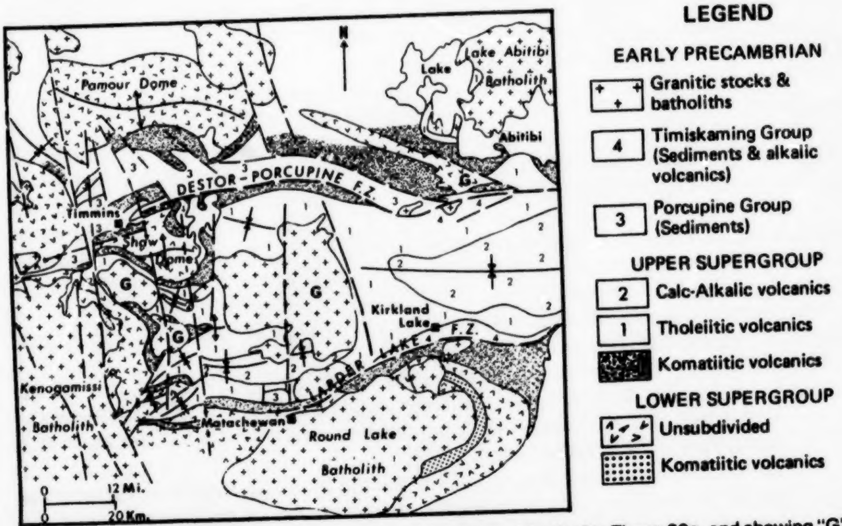

LEGEND
EARLY PRECAMBRIAN
Granitic stocks & batholiths
4 Timiskaming Group (Sediments & alkalic volcanics)
3 Porcupine Group (Sediments)
UPPER SUPERGROUP
2 Calc-Alkalic volcanics
1 Tholeiitic volcanics
Komatiitic volcanics
LOWER SUPERGROUP
Unsubdivided
Komatiitic volcanics
N
Pamour Dome
Lake Abitibi
Batholith
Abitibi
DESTOR-PORCUPINE F.Z.
Timmins
Shaw Dome
G
Kirkland Lake
LARDER LAKE F.Z.
Kenogamissi Batholith
Matachewan
Round Lake Batholith
12 Mi.
20 Km.

Figure 30b–Stratigraphy of the Timmins-Kirkland Lake Area, identical to Figure 30a, and showing "G".

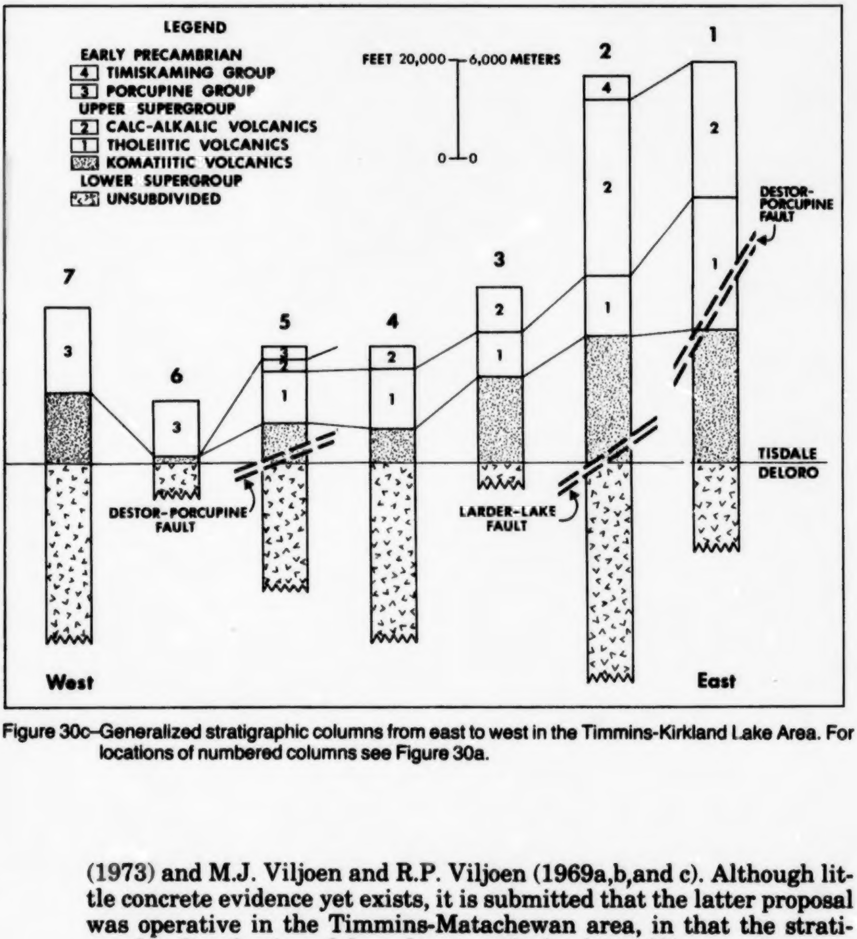

LEGEND
EARLY PRECAMBRIAN
4 TIMISKAMING GROUP
3 PORCUPINE GROUP
UPPER SUPERGROUP
2 CALC-ALKALIC VOLCANICS
1 THOLEIITIC VOLCANICS
KOMATIITIC VOLCANICS
LOWER SUPERGROUP
UNSUBDIVIDED
FEET 20,000 6,000 METERS
0 0
7
6
5
4
3
2
1
DESTOR-PORCUPINE FAULT
LARDER-LAKE FAULT
TISDALE
DELORO
West
East

Figure 30c–Generalized stratigraphic columns from east to west in the Timmins-Kirkland Lake Area. For locations of numbered columns see Figure 30a.

(1973) and M.J. Viljoen and R.P. Viljoen (1969a,b,and c). Although little concrete evidence yet exists, it is submitted that the latter proposal was operative in the Timmins-Matachewan area, in that the stratigraphic distribution of the volcanic rocks lends itself best to the interpretation that the trondhjemitic batholiths mark the sites of former volcanic complexes, possibly large shield volcanoes. In this interpretation (Figure 31 and 32), the batholiths are envisaged as products of the partial melting of the basal downwarped central part of a shield volcanic complex. The partly melted basaltic material intruded the overlying volcanic strata, and was subsequently eroded to the present level. The Lower Supergroup, peripheral to the trondhjemitic masses, represents only a part of the older volcanic sequence which has been largely destroyed by the batholiths. A detailed examination of the batholiths may reveal isolated remnants of volcanic strata hitherto undetected which may aid in deciphering additional stratigraphic elements of the Lower Supergroup.

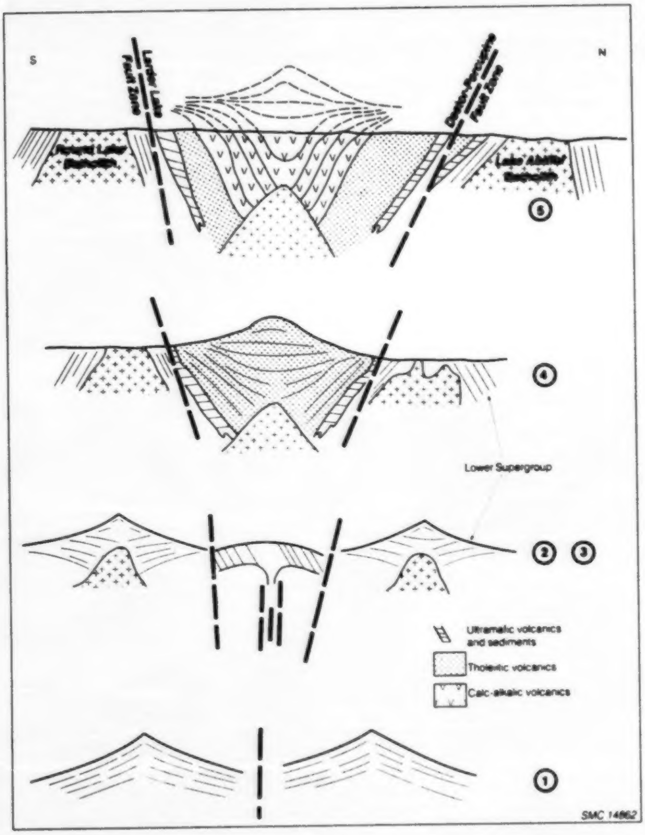

S
N
Larder Lake Fault Zone
Destor-Porcupine Fault Zone
Round Lake Batholith
Lake Abitibi Batholith
⑤
④
Lower Supergroup
② ③
Ultramafic volcanics and sediments
Tholeiitic volcanics
Calc-alkalic volcanics
①
SMC 14862

Figure 31–Diagrammatic illustration of model for evolution of part of the intrusive-volcanic complexes in the Timmins-Matachewan Area.

1)–Development of Shield Volcanic Complexes of Lower Supergroup.

2)–Rifting, with associated komatiitic volcanism and sedimentation. Marks beginning of Upper Supergroup.

3)–Partial melting and formation of trondhjemite within Lower Supergroup.

4)–Continued rifting, tholeiitic volcanism (Flood Basalts). Partial deroofing of trondhjemitic batholiths within Lower Group.

5)–Partial melting at base of Upper Supergroup, giving rise to calc-alkalic volcanism.

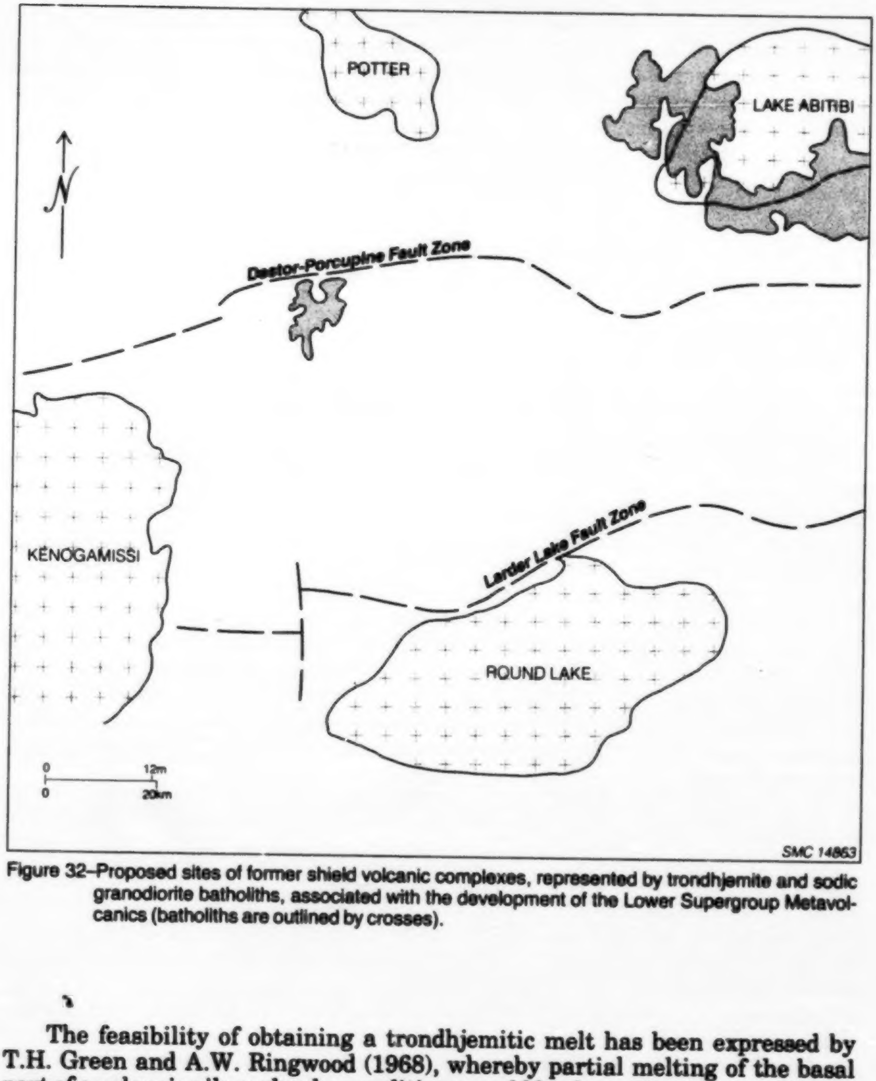

POTTER
LAKE ABITIBI
N
Destor-Porcupine Fault Zone
KENOGAMISSI
Larder Lake Fault Zone
ROUND LAKE
0
12m
0
20km
SMC 14863

Figure 32–Proposed sites of former shield volcanic complexes, represented by trondhjemite and sodic granodiorite batholiths, associated with the development of the Lower Supergroup Metavolcanics (batholiths are outlined by crosses).

The feasibility of obtaining a trondhjemitic melt has been expressed by T.H. Green and A.W. Ringwood (1968), whereby partial melting of the basal part of a volcanic pile under dry conditions would lead to a Na-rich, trondhjemitic-quartz-dioritic liquid. According to Green and Ringwood (1968), partial melting under wet conditions of a hydrous amphibole-rich rock, would yield granodioritic liquids. Figure 31 is a diagrammatic illustration of the proposed model.

The main features of this model are:

(a) Initial buildup of shield volcanic complexes (Lower Supergroup) on a primitive mafic to ultramafic crust,

(b) Subsequent rifting and outpouring of ultramafic lavas, marking the beginning of the Upper Supergroup. Extensive accumulation of sediments within and adjacent to the main rift zones. Partial melting in the downwarped central portions of the Lower Supergroup shield volcanic complexes produced a dominantly trondhjemitic melt which intrudes the overlying volcanic ejecta,

(c) Continued rifting and separation of initial shield volcanic complexes, accompanied by outpourings of the tholeiitic flood basalts (Kenojevis Group). Deroofing of trondhjemitic complexes in Lower Supergroup.

(d) Downwarping of Upper Supergroup giving rise to partial melting, thus providing a magma source for the subsequent calc-alkalic volcanism.

(e)Development of calc-alkalic volcanic complexes (Blake River Group) forming the top of the Upper Supergroup.

(f) Continued activation of the Larder Lake Fault zone in the Kirkland Lake area led to minor outpourings of alkalic volcanics and further sedimentation (Timiskaming Group).

Following the above model (Figure 32), it is suggested that north of Timmins uplift and erosion was insufficient to expose the underlying felsic intrusive phases. Perhaps, the Potter Batholith centred near the northeastern margin of the Pamour Dome is a surface expression of a much larger underlying batholith in this area. Further to the east the Lake Abitibi Batholith is interpreted to represent the former site of a shield volcanic complex.

No doubt, the above model is inadequate because it suffers many shortcomings, and is quite possibly entirely incorrect. Yet, at the same time, it does provide a conceptual model of how the volcanic- intrusive association may have developed, and may assist in developing a better or a more precise interpretation as more detailed information is accrued in this and other volcanic areas. Nevertheless, at the time of writing, the above model, in the author's opinion, has many attributes.

The granodioritic plutons in Figure 30b (denoted by the letter "G") would be interpreted either as: (1) intrusive phases related to the Upper Supergroup of volcanic rocks, or (2) potassic upper part of a largely trondhjemitic complex located at depth; the trondhjemite again, being possibly related to the Lower Supergroup. The concept that plutonism and volcanism, in this order of magnitude, can be interrelated, and are not genetically or temporally distinct, is by no means a new concept. It has been postulated for such areas as the southwestern United States for the extensive Mesozoic volcanic rocks, and batholithic complexes as well as the west coast of South America (Hamilton and Myers 1968; Bussell, Pitcher, and Wilson 1976; Pitcher 1978).

Age dating of the volcanic rocks and batholiths which is currently in progress (Nunes, in preparation), hopefully, may aid to elucidate the relationship between volcanism and plutonism.

For the reader's convenience, sample location maps for all the samples listed on microfiche sheets (in the back pocket) are shown on Figures 33, 34, and 35 (Charts A, B, and C, back pocket).

APPENDIX A

Sample Preparation and Analyses

Sample preparation and analysis, with the exception of the trace elements in those of Muir (1975), were done by the Geoscience Laboratories of the Ontario Geological Survey.

Care was taken in the field to obtain fresh unweathered samples for analysis. Nearly all the samples consisted of 0.25 to 1 kg of unweathered rock chips 3 mm to 6 cm in maximum dimension. Primary crushing in a Denver crusher (Model) reduced the chips to approximately 1.25 cm. Further crushing in a Braun pulverizer with ceramic plates brought the particle size down to less than 10 mesh. Grinding was done in a Fretsch pulverisette 5, planetary ball mill using sintered corundum (99.7 percent Al_2O_3) balls and vials. The entire sample was reduced to less then 100 mesh. The powder was mixed with lithium tetraborate ($L_{12} B_4 O_7$) as a flux and lanthanium oxide (La_2O_3) as a heavy absorber; the mixture was in the ratio 1:0.6:5. The mixture was heated in a flat bottomed graphite crucible at 1090°C for 15 minutes; the bottom of the resultant tablet was polished with silicon carbide powder and subsequently washed with water and then alcohol in an ultrasonic vibrator.

The tablets were then analysed on a computer controlled ARL (Applied Research Laboratories) X-ray spectrograph (Model 72000), for SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, K_2O, Na_2O, P_2O_5, TiO_2. The intensities of the above elements were compared to intensities of standards prepared in the same manner. Cu, Ni, Zn, and Cr were determined by atomic absorption.

APPENDIX B

Chemical Analyses Tables

Tables I to XXII inclusive (microfiche, back pocket) list all of the chemical analyses for the Timmins area. Locations of the samples are shown in Figures 33 and 34, at a scale of 1:50 000 (see back pocket). Nomenclature of the volcanic rocks as to whether calc-alkalic tholeiitic or komatiitic, and subdivisions within these fields is based on the cation proportions of Al_2O_3-(FeO + Fe_2O_3 + TiO_2)-Mg) as given by Jensen (1976).

Where values for FeO are not given, total iron was determined as Fe_2O_3. Total iron was recalculated as FeO for all samples so as to provide a rapid visual comparison between iron and other major oxides, notably MgO.

In most samples, only loss on ignition (L.O.I.) was determined rather than CO_2, H_2O+, H_2O-. In a few samples for which L.O.I. was done, CO_2 was also determined to aid in estimating degree of carbonitization.

For all the volcanic rock samples, the appropriate formation number is given. For all samples the location, by means of township (TWP), is given. The following abbreviations were used: Tis - Tisdale; Whit - Whitney; Del - Deloro; Ogd - Ogden; Moun - Mountjoy; Car - Carman; Lang - Langmuir; Eld - Eldorado; Doug - Douglas; Fal - Fallon.

APPENDIX C

Properties in the Timmins Area

A list of all the properties in the Timmins area as of September, 1973 is included with Map 2455 (back pocket). This includes both surveyed and unsurveyed claims. Figure 35 (Chart C, back pocket) is a sketch map showing the location of all the properties.

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